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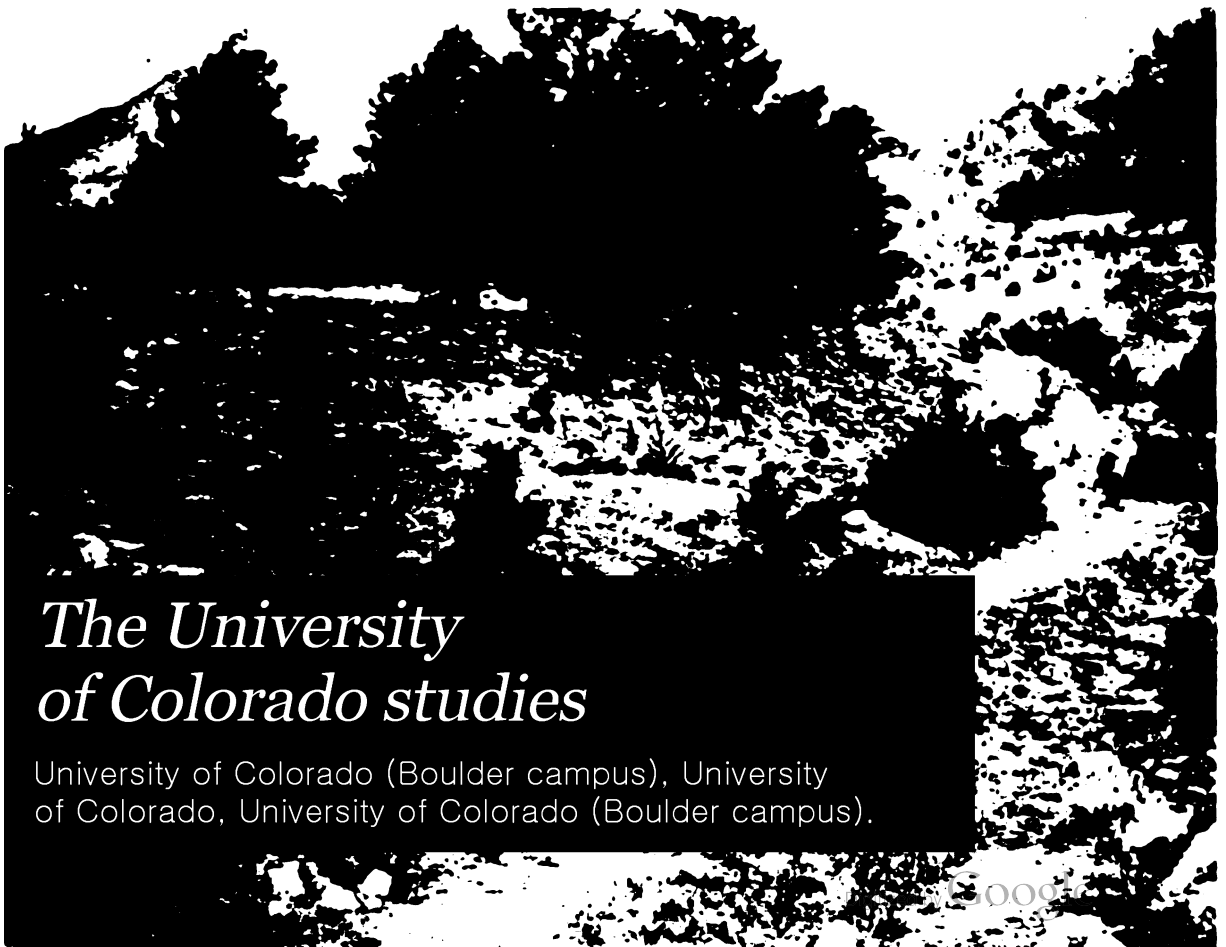

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# CONTENTS OF VOL. VI

## No. 1

PAGE

1. THE BOTANICAL OPPORTUNITY IN COLORADO . . . . . 5
FRANCIS RAMALEY, PH.D.
Professor of Biology

2. STUDIES IN MESA AND FOOTHILL VEGETATION . . . . . 11
*Geology and Physiography of the Mesas near Boulder*
GIDEON S. DODDS, M.A.
Instructor in Biology

*Climatology of the Mesas near Boulder*
FRANCIS RAMALEY, PH.D.
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*Distribution of Deciduous Trees and Shrubs on the Mesas*
W. W. ROBBINS, B.A.
Instructor in Biology

3. BIBLIOGRAPHY AND HISTORY OF COLORADO BOTANY . . 51
MISS EDITH M. ALLISON, B.A.
Assistant in Biology

## No. 2

1. THE CHARACTER OF THE FLAVIAN LITERATURE, 69–117 A. D. 81
FRED B. R. HELLEMS, PH.D.
Professor of Latin

2. THE COMPOSITION OF SOME COLORADO TUNGSTEN ORES . 93
JOHN B. EKELEY, PH.D.
Professor of Chemistry

3. GEOLOGY AND PETROGRAPHY OF THE SUGARLOAF DISTRICT, BOULDER COUNTY, COLORADO . . . . . 97
R. D. CRAWFORD, M.A.
Assistant Professor of Geology



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# THE BOTANICAL OPPORTUNITY IN COLORADO

By Francis Ramaley

To discuss botanical opportunity in Colorado may seem a needless task, for the great problems of plant life are the same the world over. Colorado, however, offers some special opportunities for study, partly because of the geology, geography and climate, and partly because here is an almost unworked field.[1] True, the total number of seed plants known for the state is very large, larger than for any state except California, but the bare record of their occurrence and collection is but a first step in botanical work.

The publication of the *Flora of Colorado*[2] should mark the beginning of an era of investigation in field and laboratory. Until the appearance of this list it was out of the question for any but a taxonomist to work with satisfaction on the flora of the state. Reference books of recent date there were none, and the scattered descriptions of plants in botanical journals were often very confusing. No one knew how many species there were in the state and few had any definite idea of their geographical distribution. This essential pioneer work of listing the plants has now been done and it is possible for botanists with other than taxonomic training to work on the problems which the plants of this interesting region present.

It must not be supposed that the knowledge of Colorado species thus far gained is at all comprehensive. There is still much room left for the collector. Many parts of the state have not been visited by botanists and even those parts that are most accessible have been imperfectly collected. There should be local lists worked out for every county. Indeed with some of our counties embracing large areas and diverse conditions nothing less than three or four lists from different points would give adequate information about the flora.

[1] The small amount of work done in Colorado botany, other than that of collecting and naming species, is seen by reference to the "Bibliography and History of Colorado Botany," pp. 51–76, in this number of these *Studies*.

[2] Rydberg, *Flora of Colo.*, Bull. 100, Colo. Agr. Exp. Sta., 1906.



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The importance of local lists is very great in such a geographical area, for they could be used by the student of distribution in working out the large problems in which he is interested. In Colorado, as in any mountainous region, the historical factors such as glaciation, climatic changes and physiographic processes are all of particular consequence. They enter into all discussions of distribution. Every local flora in its composition bears witness to their importance. Hence a series of lists for representative localities throughout the state could be made highly useful. How the plants came to be here, where they came from, why they are found in one locality and not in another—these problems can only be attacked after much more information is gathered in regard to their present-day distribution.

It is often observed that a given species of plant very common in a certain locality is entirely absent in an adjacent area, although no natural barriers to migration intervene. No doubt often this is to be explained on historical grounds. The species is extending its range from an earlier home and has not thus far reached the area where its absence is noted. In other cases no such explanation can be made, since the identical species is also present at a more distant point. Here, undoubtedly, the effects of competition with other plants have been important. Just what competition really is and how it works are little known. The student in the field can find here an opportunity for the collection and interpretation of evidence which will lead to interesting conclusions.

Since the study of elementary species in the genus *Crataegus* has brought out such an interesting array of forms, a new field in plant taxonomy has been opened to American botanists. Whatever may be thought of the propriety of naming these forms as species, it is certainly desirable that they be known and described and, if possible, their affinities determined. They could then be assembled into such larger aggregates as seemed desirable for purposes of classification. It must not be supposed that *Crataegus* is the only genus in need of thorough field study. *Opulaster* and *Rosa* besides many of the composites offer opportunities for useful work. Indeed, only the most preliminary work on the flora of Colorado has thus far been done and accurate field study in almost any genus will be well worth while.

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The plant zones of the state have not been worked out with accuracy and detail. Limits of the foothill, montane, sub-alpine and alpine zones are much in controversy and these should be studied in various parts of the state. Studies of timberline have thus far been of a very cursory type. Observational methods must be first applied, then accurate determination of altitudes of timberline in different parts of the state must be made; finally physical data of air temperature, soil temperature, soil moisture content and wind are needed. The collection and interpretation of these data would bring to an end much loose talk about altitude and plant life. Some solid basis for the discussion of the effect of altitude on plants is greatly needed and this can be attained only through such accurate studies as are here suggested.

Ability of a soil to hold or to give up moisture determines in large measure the plants which will grow in it. Large areas of Colorado have a fine-grained soil, other large areas have soil of coarser texture. The Niobrara, the Pierre, the Laramie, the White River formations have different qualities and support different floras. It happens also that over wide areas climatic conditions differ at the same time that the soil does. It should be the work of botanists to separate the effects of soil and climate so as to arrive at a rational explanation of the phenomena of the plains and foothills.

The continental divide passes north and south through the state separating two nearly equal areas. What the effect of this divide is in determining the flora to the east and west is a problem awaiting solution. A most illuminating study might be made of the plants on the two sides. They could be classified as to probable origin and the number which have crossed the divide determined with some degree of accuracy. It would probably be found that certain vegetation types are represented on both sides of the divide even if species be not the same, while the number of identical species would be found much greater than is ordinarily supposed. Carefully prepared maps illustrating vegetation areas of the eastern and western slopes are greatly needed and would help much to an understanding of the effect of the Rocky Mountains on plant distribution.

As an essential part of botanical work a thorough study of Colorado

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climatology would throw a flood of light on many difficult problems. This has been alluded to with reference to timberline studies and also with regard to questions of plant zones. Not only temperature and rainfall are of consequence but the rate of evaporation at different stations and altitudes is worth investigating. Evaporation is seldom studied by meteorologists but should be worked out by botanists if they are to get at the real climatic factors affecting plants.

Ecologically, Colorado offers an almost virgin field for study. The collection and arrangement of formation herbaria is valuable work. Such collections, representing the work of a number of seasons, are particularly useful for teaching purposes. If distributed as *exsiccati* or published as lists with suitable notes the information becomes available to botanists generally. Plants of pondsides, of meadows, of rock ridges, of alpine desert, of the forest floor, etc., may be thus collected and the specimens so arranged as to show relative abundance, time of flowering, relations to soil and moisture. Here again accurate studies of climate and of the factors involved in the soil should be made to determine why the different habitats have such different floras.

Flower ecology has been but little studied in America and almost nothing in this line of work has been done in Colorado. Entomologists and botanists working together should here find a rich field of study. As a matter of fact the insect visitors of our flowers are little known and still less is known in regard to their value in bringing about pollination. Plants of the high mountains, of the foothills and even of the great plains offer many probblems in pollination and adaptations to insect visits. Some of these are perennial problems, the same everywhere. Of how much importance the colors of flowers are in attracting insects; to what extent the scent of the flower served in alluring them—these are by no means settled questions. But putting aside these greater problems there are many smaller ones awaiting solution by the student in the field. Individual species of plants, not thus far studied from the view-point of flower ecology, are everywhere at hand ready for the student.

Facilities for distribution possessed by plants, and their ability to establish themselves on unoccupied ground are subjects for investigation. Many species enjoy a wide distribution because of devices for

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scattering seeds rather than on account of any special hardiness of the plants themselves. Very little study along this line has been made and an interesting field awaits the student who enters it. Some species, as *Achillaea*, live in all the plant zones and in nearly every possible habitat in each zone. A knowledge of the special features of such a plant which permit its wide distribution is much needed.

Because of the few botanical workers in the Rocky Mountain region very little has been done on plant anatomy. While the plants of Europe and even of the eastern United States have been much studied, the anatomy and even the details of gross structure of many Colorado species remain to be worked out. The student can make use of many large genera here which are but poorly represented elsewhere.

In the field of embryology almost nothing has been done on our native species. Since material for such work must be preserved by approved methods it is, as a rule, put up by the student who expects to work with it. Thus far neither local botanists nor visitors from the east have entered this field. While nothing startling may be expected in the embryology of Rocky Mountain plants yet interesting results may come from the investigation of species or genera not found elsewhere in the world.

A knowledge of seedling structure may furnish a key to family relationships and even to affinities of genera and species. Seedling study has not been a popular branch of botany, but will doubtless enlist more workers in the future than in the past. A particularly interesting piece of work would deal with the conditions which favor the establishment of seedlings in the soil as successful plants. The absence of conifers in the fine-grained soil of flat areas of mountain parks is largely due to inability of seedlings to get a foothold. There is much to be worked out concerning this subject and the varied conditions which exist in Colorado offer opportunities which should be embraced by students.

For the study of experimental evolution and for plant breeding a mountain region affords great advantages over ordinary situations. Here it is possible to transplant species from one situation to another having quite different climates and yet within easy reach of one another.

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If a change in climate or in soil tends to favor the development of mutations, here is the opportunity to find out what species are likely to be useful in breeding experiments. When it is remembered that in a single small area such as Boulder County there are climates ranging from that of Kentucky to northern Greenland the opportunities for studies on the effects of climate become at once apparent.

Physiological experimentation of all kinds is needed at high altitudes. Little has been done in the study of vital phenomena under the peculiar conditions of dryness and lightness of air which exist in Colorado. It is a comparatively easy matter to carry on at different altitudes experiments on transpiration, photo-synthesis and other phenomena. Work of this kind would undoubtedly prove useful, especially if done with native plants not hitherto used for experimentation.

The study of the lower plants has been much neglected in Colorado. Anyone by making collections of them would do valuable work if these collections when made were placed where they could be available for study. Specimens stored away in herbaria either within the state or outside are of little value, but published accounts, even bare lists, of algae, fungi or bryophytes would be useful and would stimulate other students to take up work in the same line. More pretentious contributions, especially such as could be put into the form of keys for the use of students, would be of still greater value. Studies of distribution with relation to climatic and other conditions would bring fruitful results.

From what has been outlined in the foregoing paragraphs it will be seen that nearly every branch of botanical study may be taken up in Colorado with hope of interesting results. This comes about partly because there has been very little botanical work done here, partly because of the great natural advantages in the varied conditions of soil and climate. Botanical workers in Colorado have been few. It is hoped that there may be more in the future. There is room and to spare for all who will come to take up problems for study. No one need fear duplication of the work of others. The botanists now resident in the state stand ready to help those who come to work and study. Let all who will make use of the "botanical opportunity in Colorado"!

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# STUDIES IN MESA AND FOOTHILL VEGETATION, I

1. *Geology and Physiography of the Mesas near Boulder*
GIDEON S. DODDS

2. *Climatology of the Mesas near Boulder*
FRANCIS RAMALEY

3. *Distribution of Conifers on the Mesas*
W. W. ROBBINS AND GIDEON S. DODDS

4. *Distribution of Deciduous Trees and Shrubs on the Mesas*
W. W. ROBBINS

## I. GEOLOGY AND PHYSIOGRAPHY OF THE MESAS

BY GIDEON S. DODDS

In the following articles is given an account of some results of investigations carried on by the writers during the seasons of 1906, 1907 and 1908. The area studied is the mesa region, at the foot of the Rocky Mountains, just at the border of the plains. Observations have been made of this area for some distance along the foothills north and south of the city of Boulder, Colorado. A more detailed study has been made of two mesas, Horse Mesa and Long Mesa, situated about two miles south of Boulder, between Boulder Creek and Bear Canyon. (See Plate I.)

The object of these studies has been to determine the conditions affecting plant distribution on the mesas. Studies have been made of physical and meteorological conditions. Many of the plant formations have been accurately mapped, and the physical characters of the different habitats determined. In articles to be published later, other plant formations will be described in relation to their habitats.

**General Appearance of the Mesas.**—The following account of the topography and structure of the mesas is taken verbatim from the report of Fenneman on this area.[1]

[1] FENNEMAN, N. M., "The Geology of the Boulder District, Colorado," *U. S. G. S. Bull. 265*, pp. 1–98 1905.



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East of the last foothill ridges the slope to the plains may be continuous or may be broken by a sharp step, leaving a high terrace adjacent to the foothills. This terrace is called a mesa, or locally "the mesa." It occurs in fragments of unequal height abutting against the most easterly foothill ridge or separated from it by a trough due to recent erosion. These fragments are commonly separated from one another by ravines. The mesas have a height of from one hundred to three hundred feet above the lower plains, and a west-east width in this vicinity varying from a fraction of a mile to three miles.

The eastward slope of the terraces may be as great as 19° on the foothill side, but it diminishes rapidly toward the plains. At one mile east from the foothills a slope of 3° or 4° is common, and at three miles the slope is 1°. An east-west cross section shows an even curve like the profile of a stream. In addition to the eastward slope there is generally a distinct northward or southward inclination toward a lower bench quite similar to the higher, but separated from it by a steep bluff, or more commonly by a ravine. In a general way the highest mesas are farthest from the larger streams and the height diminishes as these streams are approached.

**Structure and Covering.**—These mesas are essentially rock benches covered ten or twenty feet deep with unassorted rock waste. The rocks, chiefly Pierre shales, are steeply upturned, being affected by the mountain uplift. They have been smoothly planed off, not to a flat, but to an inclined surface. The débris covering may have a fairly uniform thickness of twenty feet on the highest benches. Generally speaking, the thickness is less as the mesa surface is lower. This thoroughly unassorted débris comprises fragments of all sizes from sand grains to boulders more than ten feet in diameter. The heaviest boulders are close to the foothills, but fragments a foot or more in diameter are found some miles to the east.

It is the opinion of Fenneman and most other recent writers that these mesas are, in their origin, river terraces.

### Horse Mesa and Long Mesa

**Location and Surroundings of the Mesas.**—As already stated, these two mesas are located between Boulder Creek and Bear Canyon, some two miles south of the city of Boulder. Here the Dakota "Hogback," commonly the outermost foothill ridge, is wanting, and the slope of the mesas extends unbroken with gradually increasing steepness, westward to the ridge formed by the Lyons and Fountain formations. Here the slope is very abrupt. In this locality the conglomerates of the Fountain formation are exposed in huge masses dipping at an angle of about 50° to the east. Locally these rocks are known as the "Flatirons" (Fig. 1). A mile to the west of the mesas, the summit of Green Mountain rises

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to an elevation of 8,100 feet, 2,000 feet above the level of the mesas. South Boulder Peak, farther to the south, is somewhat higher (Plate I, Fig. 2). These two mesas extend from the foothills in a northeasterly direction. Their length is about three-fourths of a mile. Eastward the slope of the plains is gentle.

**Topography of the Mesas.**—The two mesas are separated from each other and from adjacent mesas by sharp ravines. The tops are very even and unbroken. The eastward slope on the part farthest from the foothills is about seven degrees (Plate I). This even top is from 150 to 250 feet above the level of the adjacent ravines. The slope from the crest

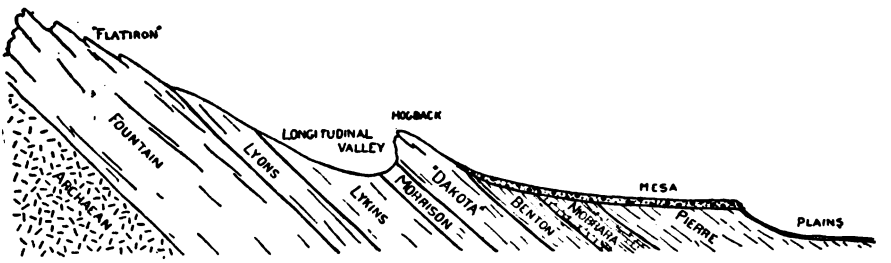


FIG. 1.—DIAGRAMMATIC REPRESENTATION OF A WEST-EAST SECTION AT THE EDGE OF THE FOOTHILL AREA.—At the west the igneous rocks of Archaean age form the mass of the foothills. To the east of the foothills in the mesa and plains region the edges of the sedimentary rocks are exposed. There are two prominent and continuous north and south ridges, one formed by the resistant strata of the Fountain conglomerate and the other by the Dakota sandstone. In places the Niobrara limestone also forms a low ridge. The diagram shows the relation and structure of the mesa. This, it will be seen, extends eastward from the Dakota "Hogback" and is underlain chiefly by Pierre shales. The rock waste of the mesa cap is derived chiefly from fragments of the Fountain and Dakota sandstones. This layer of rock waste is quite thick on the top of the mesa and much thinner on the steeply sloping sides. (After Fenneman.)

of the mesa to the bottom of the ravines is abrupt. Erosion is going on actively on the sides where the easily eroded shales are not protected by the mesa cap. Thus the top remains flat and even and the sides steep. The mesa cap also serves to keep the upper part of the slope, just below the crest of the mesa, steeper than the rest of the slope (Fig. 2).

The sides of the mesas are cut by numerous gullies, mostly small and narrow and not very deep. The slope of the sides is broken by a number

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of wider ravines, which, just below the edge of the mesa, widen out and assume an amphitheater-like form. These are of importance in relation to the distribution of moisture, as will be seen later. On Horse and Long Mesas these occur only on the south side. They are indicated on the topographic map by *X* (Fig. 3).

**Gulches.**—Bluebell and Pole Canyons head well up toward the summit of Green Mountain, while Cemetery Gulch is a younger, shorter gulch still working headward into the general surface of the mesa. In all of the gulches are intermittent streams. On account of several good springs in Bluebell Canyon it contains much more moisture than either of the other gulches and water flows in its channel during the greater part of the year. In Pole Canyon water flows during spring and early

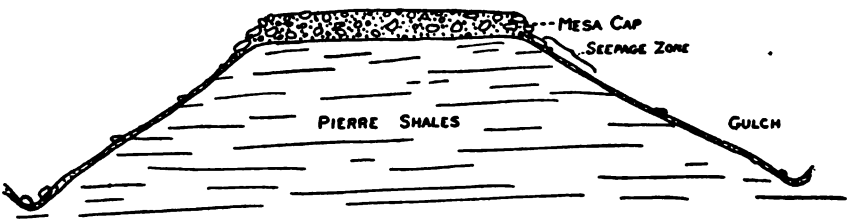


FIG. 2.—DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION OF A MESA.—This shows the underlying rock, usually Pierre shales, and the covering of rock débris. On Horse and Long Mesas the largest fragments are boulders several feet in diameter. This explains the extremely rocky zone at the edge of the mesa. The thin layer of rock waste on the steeply sloping sides is at places entirely wanting, exposing the underlying shales. Reference to the figure explains the seepage zone just below the crest of the mesa. Water percolates readily through the mesa cap to the impervious shales and at this level reaches the edge of the mesa.

summer, while Cemetery Gulch carries water only during wet weather.

Bluebell Canyon is a deep V-shaped gulch throughout the greater part of its length. Pole Canyon is deep and narrow at the foothill end of the mesa, but lower down in its course it widens out into a broader U-shaped valley. Cemetery Gulch is V-shaped with fairly steep sides.

From the above account it will be seen how great is the variety of slope and exposure on these two mesas, giving a wide diversity of conditions for plant growth. There is a difference of elevation of eight hundred feet between the highest and lowest parts of the area under study,

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but it must be remembered that in this area differences of altitude are of little consequence in determining plant distribution. The contour lines

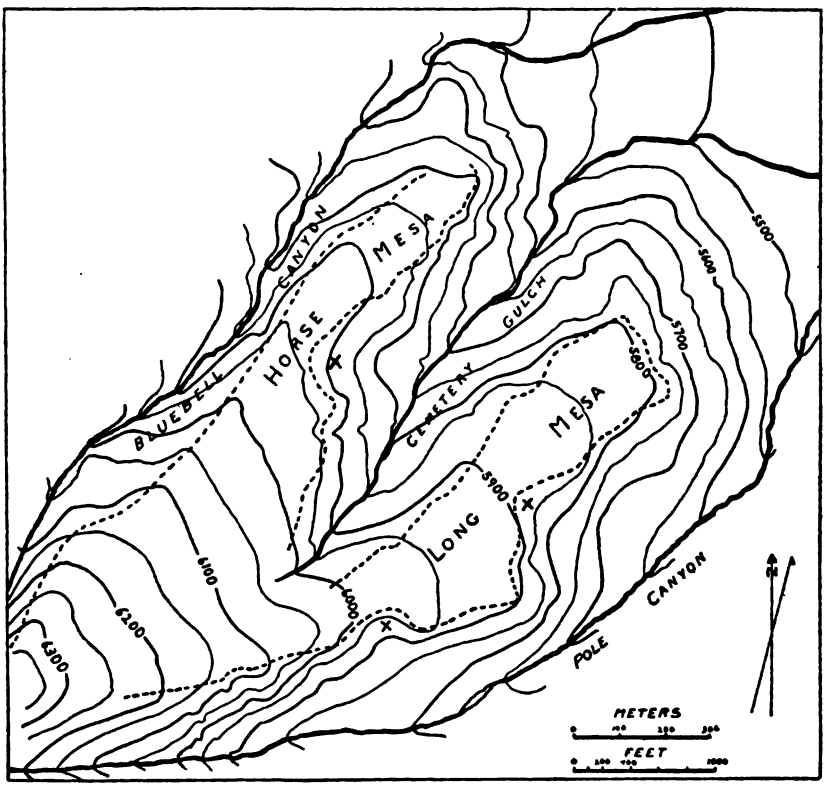


FIG. 3.—TOPOGRAPHIC MAP OF HORSE AND LONG MESAS.—Contour interval 50 feet. The numbers on the contour lines indicate feet above sea-level. The area shown is about 500 acres. The map shows clearly the even top of the mesas sloping gently toward the northeast. The limit of this even top is indicated by the broken line. Here the steep sides of the mesa begin. The sides are cut by numerous small ravines. The broad amphitheater-like ravines are indicated. Three of the more important of these are marked by *X* on the map.

on the map are not of so much importance in marking altitudes, as in showing the direction and steepness of slope.[1]

[1] The altitude seems to be of importance in the distribution of a few shrubs. See Mr. Robbins' article on "Deciduous Trees and Shrubs."

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**Methods of Mapping.**—It was found that the topographic sheets of the United States Geological Survey did not show the mesas in sufficient detail to be of use in mapping the different plant formations. This made necessary a survey of the mesas in order to construct a satisfactory map to work from. Long Mesa was mapped by first laying it off into 100-meter squares marked by stakes. These stakes served as a basis for mapping streams and other features and for drawing in contour lines. The aneroid barometer and hand level were used in mapping topography. In using the aneroid barometer in sketching topography, great care was exercised to avoid the numerous sources of error inherent in the instrument. The contour interval used was fifty feet. This is sufficiently close for the purposes of this study, and when drawn with care shows the nature of the topography in sufficient detail. On the map thus constructed, the plant formations were drawn in accurately with reference to the stakes marking the 100-meter squares. In mapping Horse Mesa a somewhat different method was employed. Here a traverse plane table with sight alidade was used. Mapping by this method is much more rapid and accurate than by the method employed on Long Mesa. By the use of the plane table a good map can be constructed with a minimum of work, and no great amount of technical knowledge is required for its manipulation.

**Soil of the Mesas.**—Two kinds of soil may be recognized on the mesas: (1) A soil of coarse texture composed of mesa cap material. (2) A fine-grained clay soil, where the absence of the mesa cap exposes the underlying shales or limestones. The texture of the mesa cap soil is coarse throughout but it varies in the quantity of large rocks and boulders mixed in it. A narrow zone just at the edge of the mesa contains a large proportion of good-sized rocks (Fig. 2). Along the gulches the soil is of somewhat finer texture than elsewhere, but there is probably none which may be classed as alluvial. Along the streams in the gulches there is a very small admixture of humus (Fig. 4).

**Soil Moisture.**—Soil moisture appears to be the most important physical factor affecting plant distribution on these mesas. During the two seasons in which observations have been made, the rainfall has been much below the normal. Neither was its seasonal dis-

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tribution normal. This is especially true of the past season (spring and summer of 1908). For this reason the records of soil moisture do not show as much as might be desired. They in all probability do not

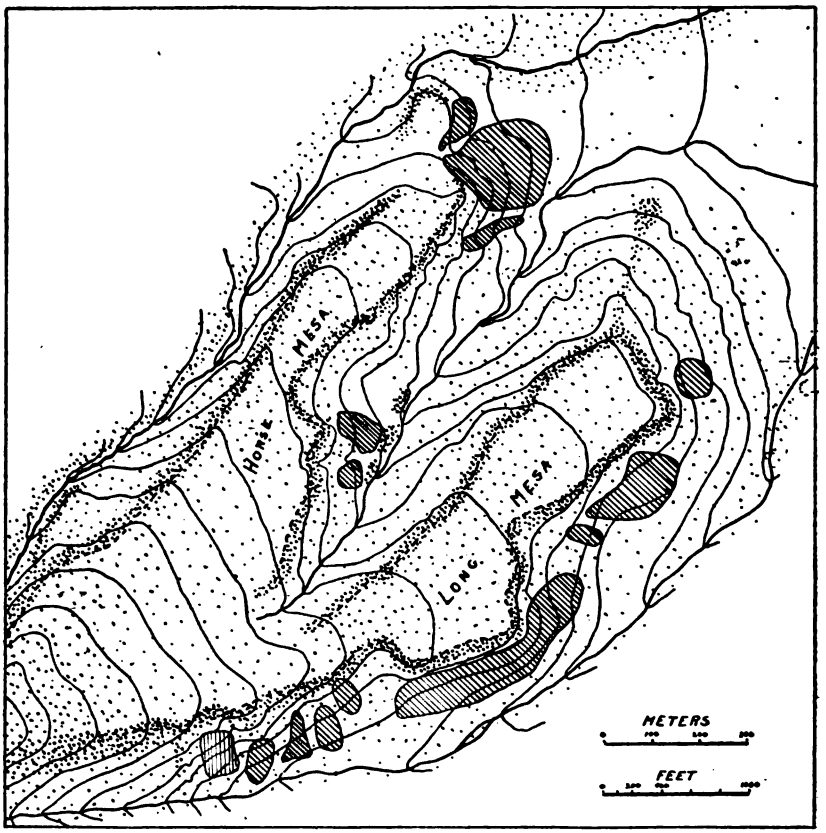


FIG. 4.—SOIL MAP OF LONG MESA AND HORSE MESA.—The greater part of the area covered by this map has a soil of sandy texture. The shading indicates the relative frequency of boulders and good-sized rocks. Note the very rocky area just at the edge of the mesa. This has a very important relation to the distribution of trees on the mesas. The portions shaded with lines are areas having a fine clay soil formed by the exposure of the underlying shales or limestones. The oblique shading indicated shales, the vertical, limestones.

show average characteristic differences between habitats, and it is entirely probable that an average yearly distribution such as observed

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the past year would not account for the present distribution of vegetation on the mesas. Soil samples have been taken at frequent intervals from different exposures and plant habitats and moisture content determined. From these data a few general facts have been ascertained, but no statement can be made of detailed differences because of the abnormality of the seasons.

**Seasonal Distribution of Soil Moisture.**—Observations indicate the following general seasonal distribution of soil moisture. At the beginning of the growing season, say about March 1, the moisture content is low in almost all of the stations. From this time on there is a gradual increase until about the last of May, when it is at a maximum. During the rest of the growing season there is a decrease. The time of the highest moisture content will of course vary in different years. Also there is no doubt that in a season of normal precipitation the maximum will occur at quite different times on different exposures. For example, it will occur later in seepage areas than on dry ridges. This may be important in its bearing on plant distribution.

**Local Distribution of Soil Moisture.**—The geographical distribution of soil moisture on the mesas has been found to bear a very important relation to plant distribution. The soil of the top of the mesa, as has been noted, is of coarse texture and covers the underlying shales to a depth of several feet. It takes up water from rains and melting snow very readily and there is little run-off from this part of the mesa. The water percolates rapidly so that after a rain the surface layer rapidly becomes dry again while the deeper layers remain wet for a longer time.

On the slopes the run-off is great. The soil is dry except in the small incipient ravines which are more moist; the deeper the ravine the greater the moisture content of its soil. In general the south slope is dryer than the north because of the more rapid evaporation.

On the slope of the mesa one feature of the distribution of moisture is especially noticeable and important in relation to plant distribution. A little distance from the crest of the mesa, just below the zone of large boulders, there is a very well-marked zone much more moist than the rest of the slope. This is especially marked in the amphitheater-like

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ravines. The explanation of this is simple. Water from snow and rain in large amounts percolates into the mesa cap of coarse texture and finds its way downward until it reaches the more impervious shales beneath. It then follows this surface until it reaches the end or edge of the mesa, where it forms a very definite seepage zone. This is shown in Fig 3. This seepage finds its way into the small ravines on the sides of the mesas but not into the soil of the ridges.

In the gulches, between the mesas, the water content is high, much higher than on the top or side. This wet zone, however, is narrow, being little wider than the bed of the intermittent streams.

## 2. Climatology of the Mesas near Boulder, Colorado

By Francis Ramaley

**Temperature and Rainfall.**—The mesas under consideration are located so near the city of Boulder that the records taken by the observer in the city may be used to give a general idea of the climate. Summers

TABLE I

Summary of Data on Temperature and Rainfall at Boulder, Colo., for Eleven Years Ending August, 1908*

| Month | Normal Mean Temperature | Warmest Mean on Record | | Coldest Mean on Record | | Normal Mean Rainfall | Greatest Rainfall on Record | | Least Rainfall on Record | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Year | Degrees | Year | Degrees | | Year | Inches | Year | Inches |
| Jan..... | 34.1 | 1906 | 39.0 | 1905 | 29.3 | 0.4 | 1899 | 0.87 | 1903 | 0.08 |
| Feb..... | 32.9 | 1907 | 42.8 | 1899 | 18.0 | 0.66 | 1903 | 1.52 | 1908 | 0.09 |
| March ..... | 39.4 | 1907 | 48.1 | 1906 | 30.2 | 1.6 | 1899 | 2.79 | 1908 | 0.23 |
| April..... | 47.7 | 1908 | 52.5 | 1900 | 45.6 | 3.58 | 1900. | 9.18 | 1908 | 1.71 |
| May..... | 56.4 | 1898 | 60.5 | 1907 | 51.0 | 3.02 | 1904 | 5.35 | 1899 | 0.55 |
| June.. .... | 64.6 | 1902 | 66.8 | 1907 | 62.1 | 1.53 | 1897 | 3.71 | 1908 | 0.29 |
| July..... | 70.1 | 1901 | 75.3 | 1906 | 67.2 | 1.72 | 1906 | 3.81 | 1901 | 0.46 |
| Aug..... | 71.0 | 1898 | 73.2 | 1906 | 68.0 | 1.3 | 1897 | 3.3 | 1900 and 1905 | 0.22 |
| Sept..... | 64.0 | 1897 | 66.8 | 1900 | 61.5 | 1.55 | 1902 | 2.7 | 1901 | 0.10 |
| Oct..... | 53.0 | 1900 | 57.2 | 1905 | 48.5 | 1.47 | 1903 | 3.43 | 1900 | 0.13 |
| Nov..... | 43.0 | 1904 | 48.3 | 1898 | 38.1 | 0.59 | 1906 | 1.87 | 1899 and 1901 | 0.00 |
| Dec..... | 37.0 | 1906 | 41.0 | 1898 | 29.0 | 0.68 | 1902 | 0.54 | 1905 and | 0.00 |
| Annual..... | 51.0 | | | | | 18.0 | | | 1906 | |

* The following additional data serve to show the extreme conditions. The highest recorded temperature is 97 degrees, on July 15, 1902, the lowest is −20 degrees, recorded January 8, 1902, and again February 20, 1905. In 1906 the greatest rainfall was recorded, it being 26.17 inches, while 1901 was the driest year with a rainfall of 13.67 inches.

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are warm and dry; winters are mild with little precipitation. Snowfall is not sufficient for sleighing except in unusual seasons. Most of the snow comes in early spring, frequently melting as it falls. The region is semi-arid; mesophytic plants grow only in gulches or seepage areas unless irrigated. Precipitation is, however, greater than on the

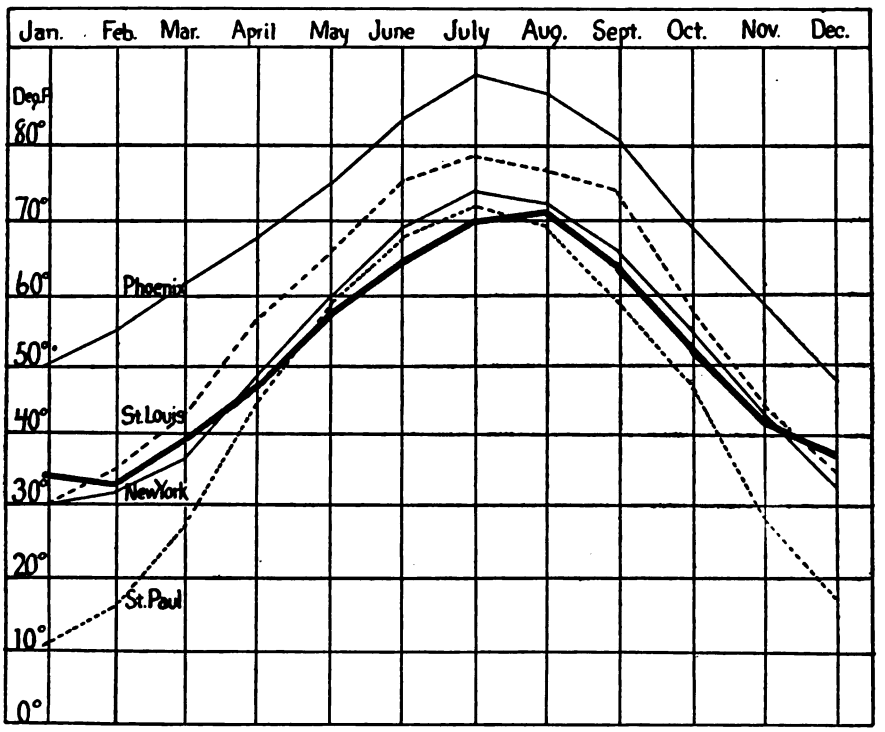


FIG. 1.—ANNUAL MARCH OF TEMPERATURE.—Boulder (heavy black line) compared with St. Paul, New York, St. Louis and Phoenix, Ariz. The mean temperature for December and for January is seen to be higher at Boulder than in New York or St. Louis while the summer temperature is lower at Boulder than in these cities or even St. Paul.

plains, Boulder having about four inches more rainfall than Denver which is on the plains about twenty-five miles away. The general character of the climate is shown in Table I, kindly prepared by Hon. S. A. Giffin, voluntary observer at Boulder.

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**Temperature Compared with That of Other Parts of the United States.**—The climate of Boulder may be called mild; since American climates with which it is likely to be compared are more severe. The mean for the year is about the same as that of New York City, but the winters in Boulder are warmer and the summers cooler. Briefly described it may be said that Boulder is as warm in winter as St. Louis and as cool in summer as St. Paul. The relation of the climate of Boulder to

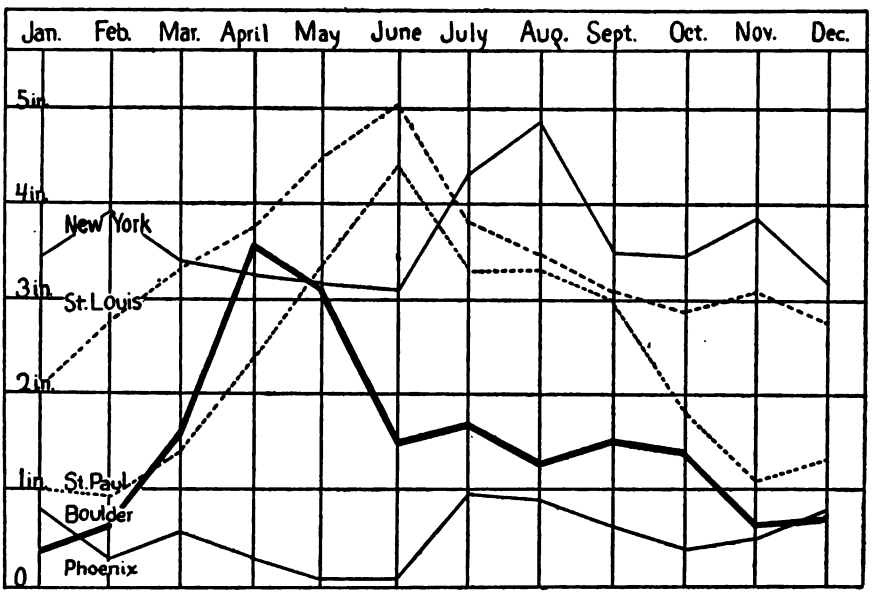


FIG. 2.—RAINFALL BY MONTHS.—Boulder (heavy black line) compared with New York, St. Louis, St. Paul and Phoenix, Ariz. It is seen from the shape of the curve that the general distribution of rainfall is about the same in Boulder as in St. Louis and St. Paul. The month of greatest rainfall at Boulder is April instead of June, as in the Mississippi valley cities. Comparison with rainfall of Phoenix, Ariz., shows that Boulder is in no sense to be considered as a desert station.

that of New York, St. Paul, St. Louis and Phoenix, Ariz., is shown in Fig. 1. The warm winters at Boulder may be expected to permit the growth of southern plants which are able to survive here when they would be unable to live if winters were more rigorous. On the other hand, the coolness of summer is favorable to the growth of northern

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species which would be killed by the greater heat of the plains. This question will be more fully discussed in a later paper.

**Precipitation Compared with That of Other Parts of the United States.**—The mean annual precipitation is eighteen inches at Boulder. Hence the climate may be described as semi-arid, but not as desert. Since evaporation is less rapid at Boulder than on the great plains the eighteen inches of rainfall really goes farther than the same amount would in eastern Colorado or western Nebraska. The precipitation at Boulder is 40 per cent. that at New York and 65 per cent. that at St. Paul, Minn. Fig. 2 shows graphically the mean rainfall by months

TABLE II

SUMMARIES OF RELATIVE HUMIDITY READINGS AT BOULDER, COLO., 1908

| | June | July | August* |
|---|---|---|---|
| | % | % | % |
| Monthly mean, using 6 A. M. and 6 P. M. | 63.3 | 66.5 | 78.3 |
| Monthly mean, calculated from maximum and minimum | 65.8 | 67.9 | 75.1 |
| Monthly mean, using 2 A. M., 8 A. M., 2 P. M. and 8 P. M. | 63.2 | .... | .... |
| Monthly mean, using 8 A. M. and 8 P. M. | 65.4 | .... | .... |
| Mean daily maximum | 84.6 | 86.3 | 91.8 |
| Mean daily minimum | 47.1 | 49.5 | 58.5 |
| Mean daily range | 37.5 | 36.8 | 33.3 |
| Greatest daily range | 92.0 | 56.0 | 58.0 |
| Least daily range | 11.0 | 16.0 | 10.0 |
| Highest maximum | 100.0 | 100.0 | 100.0 |
| Lowest maximum | 47.0 | 61.0 | 69.0 |
| Highest minimum | 60.0 | 69.0 | 79.0 |
| Lowest minimum | 8.0 | 27.0 | 33.0 |

* August, 1908, was unusually wet. The precipitation was 3.3 inches, being 2 inches above normal.

for Boulder, New York, St. Louis, St. Paul and Phoenix, Ariz. The last-named place is included as a representative of desert conditions.

**Wind.**—Although Colorado has a reputation for high winds the total wind movement at Denver (twenty-five miles from Boulder) is less than in many parts of the eastern United States. The mean annual movement of wind in Denver is 62,621 miles which is less than that of such eastern cities as Chicago with 136,454 miles, Boston 101,907, New York 96,769, St. Louis 96,016 and St. Paul 63,000.[1] Unfortunately no wind records are available for Boulder. The wind at Boulder

[1] EDSON, CARROLL E., "Denver," *Wood's Ref. Handb. Med. Sci.*, Vol. III, pp. 408–11, 1901.

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is usually from the east in the daytime during fair weather and from the west at night. High winds are only from the west. These come at

TABLE III

RECORDS OF RELATIVE HUMIDITY AT BOULDER, COLO., JUNE, 1908, GIVEN IN PERCENTS

| Date | 2 A. M. | 8 A. M. | 2 P. M. | 8 P. M. | Date | 2 A. M. | 8 A. M. | 2 P. M. | 8 P. M. |
|---|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | | % | % | % | % |
| June 1..... | 49 | 44 | 50 | 70 | June 16..... | 100 | 70 | 49 | 66 |
| 2..... | 98 | 79 | 56 | 80 | 17..... | 73 | 78 | 80 | 81 |
| 3..... | 80 | 66 | 25 | 18 | 18..... | 69 | 60 | 54 | 59 |
| 4..... | 30 | 36 | 32 | 45 | 19..... | 69 | 60 | 38 | 43 |
| 5..... | 42 | 53 | 37 | 36 | 20..... | 46 | 61 | 42 | 41 |
| 6..... | 43 | 54 | 50 | 79 | 21..... | 40 | 49 | 40 | 51 |
| 7..... | 80 | 68 | 60 | 90 | 22..... | 42 | 92 | 81 | 84 |
| 8..... | 92 | 78 | 39 | 58 | 23..... | 80 | 74 | 60 | 67 |
| 9..... | 64 | 62 | 53 | 70 | 24..... | 64 | 80 | 60 | 55 |
| 10..... | 96 | 65 | 55 | 70 | 25..... | 63 | 87 | 61 | 60 |
| 11..... | 100 | 71 | 15 | 10 | 26..... | 96 | 62 | 41 | 45 |
| 12..... | 67 | 59 | 38 | 56 | 27..... | 73 | 72 | 54 | 48 |
| 13..... | 93 | 100 | 69 | 80 | 28..... | 65 | 83 | 76 | 85 |
| 14..... | 85 | 67 | 67 | 90 | 29..... | 42 | 90 | 79 | 63 |
| 15..... | 100 | 90 | 54 | 100 | 30..... | 48 | 56 | 54 | 61 |

TABLE IV

MAXIMUM AND MINIMUM RELATIVE HUMIDITY FOR EACH DAY OF JUNE, 1908, AT BOULDER, COLO.

| Date | Highest | Lowest | Range | Date | Highest | Lowest | Range |
|---|---|---|---|---|---|---|---|
| June 1..... | 90 | 38 | 52 | June 16..... | 100 | 47 | 53 |
| 2..... | 100 | 56 | 44 | 17..... | 94 | 76 | 18 |
| 3..... | 85 | 16 | 69 | 18..... | 71 | 42 | 29 |
| 4..... | 47 | 30 | 17 | 19..... | 76 | 36 | 40 |
| 5..... | 57 | 36 | 21 | 20..... | 68 | 40 | 28 |
| 6..... | 80 | 50 | 30 | 21..... | 53 | 39 | 14 |
| 7..... | 92 | 48 | 44 | 22..... | 96 | 80 | 16 |
| 8..... | 100 | 35 | 65 | 23..... | 100 | 57 | 43 |
| 9..... | 75 | 47 | 28 | 24..... | 90 | 53 | 47 |
| 10..... | 100 | 46 | 54 | 25..... | 90 | 56 | 34 |
| 11..... | 100 | 8 | 92 | 26..... | 100 | 39 | 61 |
| 12..... | 66 | 35 | 31 | 27..... | 77 | 49 | 28 |
| 13..... | 100 | 60 | 40 | 28..... | 92 | 74 | 18 |
| 14..... | 91 | 60 | 31 | 29..... | 90 | 62 | 28 |
| 15..... | 100 | 54 | 46 | 30..... | 58 | 47 | 11 |

a time of low barometer and are always warm and dry. Typical high winds from the mountain are known as "chinooks." A chinook in winter will melt snow very rapidly and raise the air temperature twenty

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or thirty degrees during the first hour that it blows.[1] Continued east winds both day and night bring rain or snow. West winds are almost invariably dry and are not accompanied by rain except slight thundershowers.

**Relative Humidity.**—Evaporation is rapid, the relative humidity being low. Records for Boulder taken with a Draper hygrometer on the University campus are given in Tables II, III and IV. These show a somewhat low relative humidity as compared with stations in the eastern and central United States, but a much higher degree of saturation than exists in the great basin or the desert southwest. The readings at Boulder are higher than those of the weather bureau at Denver. This

TABLE V

RECORD OF CLOUDINESS AT BOULDER; AVERAGES FOR ELEVEN YEARS ENDING DECEMBER 31, 1907*

| Month | Clear Days | Partly Cloudy Days | Cloudy Days | Month | Clear Days | Partly Cloudy Days | Cloudy Days |
|---|---|---|---|---|---|---|---|
| January..... | 21 | 7 | 3 | August..... | 14 | 16 | 1 |
| February.... | 15 | 10 | 3 | September.... | 18 | 10 | 2 |
| March..... | 16 | 11 | 4 | October..... | 21 | 7 | 3 |
| April..... | 15 | 9 | 6 | November.... | 20 | 9 | 1 |
| May..... | 12 | 14 | 5 | December .... | 20 | 8 | 3 |
| June..... | 15 | 13 | 2 | | | | |
| July..... | 15 | 14 | 2 | Year..... | 202 | 128 | 35 |

* Kindly furnished by Hon. S. A. Giffin, voluntary observer at Boulder.

is partly accounted for by the location of the instrument which is placed in a shelter only a few feet above sod, while weather bureau observations are taken from a roof high above the ground. However, Boulder should have a higher relative humidity because of its greater rainfall than Denver. In comparison with the Mississippi valley and the states to the east evaporation is rapid. South slopes of mesas and foothills furnish rather severe conditions for plant growth and so they are much more poorly clad with timber than north slopes. Since dew falls but seldom, perhaps four or five times in a month during summer, it follows that evaporation continues during the night as well as the day. In Table II the mean relative humidity at Boulder during June,

[1] See HANN, *Handbook of Climatology*, p. 360.

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July and August, 1908, is seen to be 65.8, 67.9 and 75.1 respectively, as calculated from maxima and minima. These figures seem high for a "dry climate" and they are probably higher than the normal since the present summer has been singularly free from wind and in August the precipitation was very high with nearly two weeks of rainy weather. The details for the month of June given in Tables III and IV are of interest in showing more exactly the state of the air with reference to humidity.

**Direct Heat of the Sun.**—This is great in all mountain districts because of the thinness of the air. Also because of this thinness the air cools rapidly or does not retain heat. There is then a great difference in temperature between sun and shade. Boulder has a sufficient altitude to show these phenomena although not to so great an extent as high mountain districts. More marked differences may be expected between sun plants and shade plants than at sea-level or low altitudes generally. The papers in the present number of the *Studies* do not take up sun and shade plants but work on these forms is planned for publication at an early date.

**Light.**—Sunlight at Boulder and on the mesas under discussion is very brilliant and frequently continuous all day long. Very few days are entirely cloudy even at the time of April and May storms. The number of clear, cloudy and partly cloudy days is shown in Table V. It will be noted that during the entire summer there are only five cloudy days while about half of the days are partly cloudy. During the spring rains and snows, clouds or fog may hang over the mesas and above the town of Boulder but after the growing season there is no fog. Mornings throughout the summer are almost invariably clear, while from 12 to 4 o'clock it is often partly cloudy. Because of this large amount of sunlight true shade plants are very scarce except in the darkest gulches or underneath trees with dense foliage. The growth of "green slime" so common on north walls and fences throughout the Atlantic states is not found in Colorado at all. Mosses and ferns also are scarce because of bright light and dryness of air.

**Comparison of Mesas and Plains.**—Since the mesas support a growth of coniferous trees while the plains a few hundred feet lower down

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show only grassland, an inquiry into the differences is of interest. There can be no doubt that the coarseness of the soil of mesas favors tree growth.

TABLE VI

TEMPERATURES AT UNIVERSITY CAMPUS AND HORSE MESA

| DATE 1908 | MAXIMA | | MINIMA | | DAILY RANGE | | DATE 1908 | MAXIMA | | MINIMA | | DAILY RANGE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Campus | Mesa | Campus | Mesa | Campus | Mesa | | Campus | Mesa | Campus | Mesa | Campus | Mesa |
| March 8 | 38 | 35 | 18 | 17 | 20 | 18 | 20 | 72 | 70 | 49 | 50 | 23 | 20 |
| 9 | 52 | 50 | 20 | 24 | 32 | 26 | 21 | 73 | 71 | 45 | 49 | 28 | 22 |
| 10 | 61 | 59 | 29 | 31 | 32 | 28 | 22 | 75 | 75 | 48 | 52 | 27 | 23 |
| 11 | 66 | 64 | 42 | 44 | 24 | 20 | 23 | 55 | 54 | 49 | 49 | 6 | 5 |
| 12 | 59 | 56 | 43 | 46 | 16 | 10 | 24 | 60 | 59 | 45 | 44 | 15 | 15 |
| 13 | 64 | 62 | 43 | 46 | 19 | 16 | 25 | 46 | 46 | 42 | 40 | 4 | 6 |
| 14 | 64 | 60 | 53 | 52 | 11 | 8 | 26 | 54 | 52 | 27 | 30 | 27 | 22 |
| 15 | 66 | 64 | 56 | 55 | 10 | 9 | 27 | 64 | 63 | 29 | 32 | 35 | 31 |
| 16 | 71 | 70 | 53 | 55 | 18 | 15 | 28 | 45 | 42 | 29 | 32 | 16 | 10 |
| 17 | 69 | 68 | 56 | 57 | 13 | 11 | 29 | 59 | 56 | 23 | 26 | 36 | 30 |
| 18 | 59 | 59 | 36 | 33 | 23 | 26 | 30 | 54 | 50 | 32 | 31 | 22 | 19 |
| 19 | 42 | 40 | 27 | 25 | 15 | 15 | May 1 | 67 | 65 | 34 | 37 | 33 | 28 |
| 20 | 61 | 60 | 20 | 22 | 41 | 38 | 2 | 79 | 78 | 40 | 42 | 39 | 36 |
| 21 | 47 | 47 | 42 | 42 | 5 | 5 | 2 | 47 | 45 | 42 | 41 | 5 | 4 |
| 22 | 53 | 51 | 26 | 24 | 27 | 27 | 4 | 32 | 30 | 32 | 28 | 0 | 2 |
| 23 | 60 | 57 | 38 | 40 | 22 | 17 | 5 | 40 | 42 | 27 | 29 | 13 | 13 |
| 24 | 62 | 61 | 42 | 45 | 20 | 16 | 6 | 60 | 59 | 31 | 36 | 29 | 33 |
| 25 | 73 | 72 | 55 | 55 | 18 | 17 | 7 | 67 | 67 | 32 | 40 | 35 | 27 |
| 26 | 53 | 51 | 26 | 25 | 27 | 26 | 8 | 69 | 69 | 36 | 42 | 33 | 27 |
| 27 | 50 | 47 | 26 | 25 | 24 | 22 | 9 | 59 | 62 | 39 | 39 | 20 | 23 |
| 28 | 42 | 40 | 24 | 25 | 18 | 15 | 10 | 55 | 56 | 36 | 41 | 19 | 15 |
| 29 | 57 | 54 | 24 | 26 | 33 | 28 | 11 | 65 | 66 | 38 | 40 | 27 | 26 |
| 30 | 60 | 58 | 40 | 40 | 20 | 18 | 12 | 62 | 64 | 44 | 48 | 18 | 16 |
| 31 | 57 | 55 | 42 | 43 | 15 | 12 | 13 | 59 | 57 | 35 | 38 | 24 | 19 |
| April 1 | 44 | 42 | 24 | 25 | 20 | 17 | 14 | 69 | 69 | 38 | 44 | 31 | 25 |
| 2 | 52 | 50 | 20 | 19 | 32 | 31 | 15 | 75 | 75 | 41 | 45 | 34 | 30 |
| 3 | 70 | 65 | 32 | 36 | 38 | 29 | 16 | 77 | .. | 50 | .. | 27 | .. |
| 4 | 66 | 65 | 42 | 46 | 24 | 19 | 17 | 73 | 75 | 58 | 60 | 15 | 15 |
| 5 | 69 | 67 | 33 | 34 | 36 | 33 | 18 | 74 | 76 | 48 | 54 | 26 | 22 |
| 6 | 68 | 67 | 52 | 55 | 16 | 12 | 19 | 85 | 86 | 49 | 59 | 36 | 27 |
| 7 | 52 | 50 | 35 | 35 | 17 | 15 | 20 | 60 | 60 | 44 | 46 | 16 | 14 |
| 8 | 48 | 46 | 29 | 27 | 19 | 19 | 21 | 62 | 60 | 28 | 33 | 34 | 27 |
| 9 | 70 | 67 | 34 | 36 | 36 | 31 | 22 | 66 | 64 | 42 | 47 | 24 | 17 |
| 10 | 70 | 65 | 40 | 44 | 30 | 21 | 23 | 64 | 64 | 44 | 45 | 20 | 19 |
| 11 | 74 | 70 | 35 | 36 | 40 | 34 | 24 | 45 | 48 | 44 | 46 | 1 | 2 |
| 12 | 78 | 75 | 54 | 58 | 26 | 17 | 25 | 69 | 70 | 43 | 45 | 26 | 25 |
| 13 | 76 | 75 | 52 | 55 | 21 | 20 | 26 | 71 | 74 | 44 | 50 | 27 | 24 |
| 14 | 76 | 76 | 57 | 58 | 19 | 18 | 27 | 57 | 57 | 40 | 40 | 17 | 17 |
| 15 | 57 | 57 | 41 | 41 | 16 | 16 | 28 | 56 | 58 | 38 | 44 | 18 | 14 |
| 16 | 70 | 66 | 43 | 43 | 27 | 23 | 29 | 69 | 70 | 36 | 40 | 33 | 30 |
| 17 | 69 | 67 | 45 | 47 | 24 | 20 | 30 | 65 | 64 | 41 | 46 | 24 | 18 |
| 18 | 72 | 72 | 46 | 56 | 26 | 16 | 31 | 66 | 66 | 42 | 48 | 24 | 18 |
| 19 | 78 | 68 | 53 | 50 | 25 | 18 | | | | | | | |

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Other factors are, however, of importance. The mesas are not uniformly covered with trees even where the soil is coarse. North slopes have much more timber on them than south slopes. Here, evidently, soil moisture, evaporation and direct heat of the sun play an important part.

**Thermograph Records.**—To compare climatic conditions on the mesa and adjacent plain two thermographs were kept running during

TABLE VII

MEAN TEMPERATURES* FOR THE SPRING MONTHS OF 1908 AT UNIVERSITY CAMPUS AND HORSE MESA (MEAN = MAXIMUM + MINIMUM + 2)

| Station | March | April | May |
|---|---|---|---|
| | F. | F. | F. |
| University Campus..... | 47.2 | 51.6 | 51.0 |
| Horse Mesa..... | 46.5 | 51.4 | 53.1 |

* The mean temperatures for the two stations except for May are nearly the same, although, as shown in Table VI, the maxima and minima differ considerably.

TABLE VIII

COMPARISON OF TEMPERATURES AT CAMPUS AND MESA, MAY, 1908

| | Campus | Mesa |
|---|---|---|
| Monthly mean*..... | 51.5 | 54.1 |
| Mean maximum..... | 61.5 | 61.0 |
| Mean minimum..... | 38.1 | 41.5 |
| Mean daily range..... | 23.2 | 19.5 |
| Number of days on which the temperature went to 32 degrees or lower..... | 5 | 2 |
| Date of latest frost..... | May 21 | May 5 |

* Calculated by the formula 7 A. M. + 2 P. M. + 9 P. M. + 9 P. M. + 4 = *mean*.

the spring of 1908. The months of March, April and May are critical ones for most plants in this region. Plants which get through the winter successfully are often killed by late frosts following warm weather in March and April. The instruments used in the present study were placed in suitable shelters of identical pattern, one on the campus of the University at an altitude of 5,420 feet, the other on Horse Mesa, a mile to the south, at an altitude of 5,835 feet. The campus station, although so close to the mesas and foothills, may be considered as at the upper

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limit of the plains. In fact the campus, though now planted with trees, was originally an arid plain. The mesa station is at the lower limit of timber. Both stations are exposed to the unobstructed sun at all times.[1]

**Climate of Mesa and Plain.**—In Table VI are given the maximum, minimum and range for each day during which the thermograph was kept in operation on the mesa. The figures show the differences in the climate of the two places. The campus has higher maxima and

TABLE IX

DAILY MEANS* FOR MAY, 1908, AT UNIVERSITY CAMPUS AND HORSE MESA

| Day of Month | Mean Temperature at Campus | Mean Temperature on Mesa | Day of Month | Mean Temperature at Campus | Mean Temperature on Mesa |
|---|---|---|---|---|---|
| 1 | 53.0 | 59.0 | 17 | 63.0 | 65.5 |
| 2 | 63.5 | 64.5 | 18 | 62.5 | 68.7 |
| 3 | 37.2 | 33.7 | 19 | 68.5 | 72.5 |
| 4 | 28.2 | 28.0 | 20 | 50.2 | 52.0 |
| 5 | 30.2 | 35.0 | 21 | 51.2 | 52.5 |
| 6 | 45.0 | 54.5 | 22 | 51.7 | 59.5 |
| 7 | 51.0 | 55.2 | 23 | 49.2 | 48.0 |
| 8 | 53.0 | 54.2 | 24 | 44.2 | 47.0 |
| 9 | 47.2 | 48.5 | 25 | 54.7 | 58.5 |
| 10 | 45.7 | 46.2 | 26 | 58.0 | 62.0 |
| 11 | 55.5 | 55.2 | 27 | 48.5 | 49.7 |
| 12 | 52.5 | 53.5 | 28 | 48.2 | 49.2 |
| 13 | 43.0 | 48.5 | 29 | 56.2 | 37.5 |
| 14 | 54.0 | 57.2 | 30 | 56.5 | 58.7 |
| 15 | 59.5 | 63.0 | 31 | 54.5 | 57.0 |
| 16 | 65.5 | 68.2 | Month | 51.5 | 54.1 |

* Mean temperatures were calculated according to the formula recommended by Hann: 7 A. M. + 2 P. M. + 9 P. M. + 9 P. M. + 4 = *mean*. The formula: *maximum* + *minimum* + 2 = *mean*, differed from the above considerably for individual days but for the month the mean differed only 0.5 degree for the campus and one degree for the mesa. See Table VII.

lower minima than the mesa. In other words, the plain has a more severe climate than the mesa. Days are hotter and nights are colder. The mean temperatures, however, do not differ greatly (Table VII). No observations have been made on the rainfall of the mesas but they probably have a slightly greater precipitation than the adjacent plain.

**Inversion of Temperatures.**—It is ordinarily the case that increased altitude is accompanied by lower temperature, but low hills surrounding

[1] The only published data dealing with the climate of this area in reference to plant formations are given by YOUNG, *Bot. Gaz.*, 44:334, 337, 339, 1907. Dr. Young's observations, while interesting, are so fragmentary that they cannot be used in the present study.

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mountain valleys usually have a higher temperature on clear nights than the plain below.[1] This is well shown in the present study where at times a difference of ten degrees occurred in the minimum of the two stations (Table VI). During the month of May these higher minima of the mesa brought up the mean two degrees above that of the campus. It may be well to point out that the campus station is not in a gulch or near the creek where night temperatures are expected to be cool, but on a sloping hillside about a quarter of a mile to the south of the creek and two hundred feet higher. Late frosts of the spring which injure vegetation of the plain do not reach the mesa. In the present year the last frost was sixteen days later on the plain than on the mesa (Table VIII). In Table IX a comparison between University campus and Horse Mesa is made with regard to daily means for May, 1908. Figures 3 and 4 illustrate graphically the differences in maxima and minima at the two stations for certain selected weeks.[2]

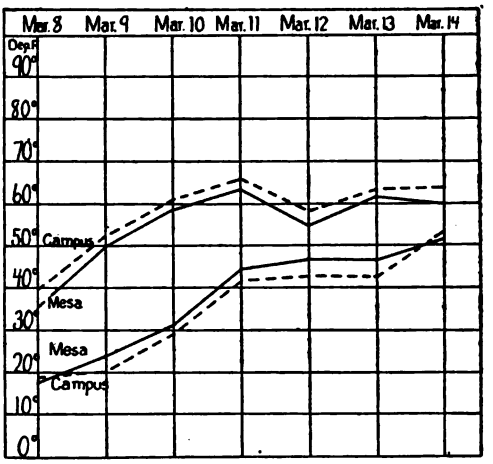


FIG. 3.—MAXIMUM AND MINIMUM TEMPERATURES OF CAMPUS AND MESA FOR THE WEEK MARCH 8 TO MARCH 14, 1908.—The campus maximum is about two to three degrees higher each day and the campus minimum lower than the corresponding readings at the mesa. The campus, representing plains conditions, has a more severe climate than the mesa.

**Severity of the Plains Climate.**—Since the University campus is close to the mesas it does not show as great a difference in climate as would be found on the plains to the east. Many cultivated shrubs which are hardy at Boulder will not live even five miles out on the plains. Hence the figures in the tables do not, by any means, represent extreme conditions of mesas and plains. The figures tell too little instead of

[1] HANN, *Handbook of Climatology* (Ward's translation), p. 252, 1903.

[2] See in this connection a note by the present writer in *Science*, N. S., Vol. XXVIII, p. 695, 1908.

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too much. At the city of Longmont which is on the plains about fifteen miles from Boulder the temperature on cold winter nights is sometimes ten or twenty degrees lower than at Boulder. On the other hand, in warm weather of winter or spring the plains have a higher temperature than the mesas, and plants may begin their spring growth so early that they are injured by late frosts. Denver, situated about twenty miles east of the foothills, has a climate much more severe than that of Boulder. The winters are colder, the summers warmer and the annual precipitation less.

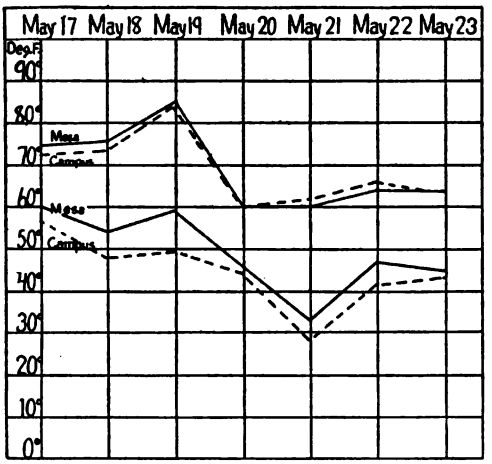


FIG. 4.—MAXIMUM AND MINIMUM TEMPERATURES OF CAMPUS AND MESA FOR THE WEEK MAY 17 TO MAY 23, 1908.—During this week the temperature was lower every night on the campus than on the mesa. On May 19 there was a difference of ten degrees. On May 21 there was frost on the campus (twenty-eight degrees F.) while the latest frost on the mesa came May 5.

**Floras of Mesa and Plain.**—Differences in both soil and climate work together to give different floras to mesa and plain. The coniferous trees, so conspicuous a feature of the foothills, become sparse on the mesas and are entirely absent from the plains. Other plants as well—shrubs and herbs—make here their last stand in a fight against unfavorable conditions. From the study of the climate as well as from observation of the flora it appears that plains plants have no difficulty in living on the mesas but that foothill plants coming down to the mesas do not readily pass beyond to the plains.

**Good and Bad Years for Seedlings.**—During some seasons and even for a series of years the climate may be especially mild and moist. This results in the establishment of trees on the mesas far out beyond their ordinary range. A series of dry and cold winters may follow when only the strongest of the recently established seedlings are able to live. No

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new ones can get a start. So it happens on some mesas that there are old trees of one hundred or two hundred years, then others twenty or thirty years old and none of intervening age. Ability to become successfully established depends largely on the periodicity of climatic conditions. Once a tree is fairly started and as old as five or six years it is able to withstand a number of unfavorable seasons and is likely to continue to grow without interruption.

**Variation in Climatic Conditions.**—By reference to the tables previously given it will be seen that there is some variation in temperature and rainfall at Boulder from year to year. While in any series of years the mean temperature and rainfall may be counted on with some certainty yet individual years may show a considerable departure from the normal. Boulder does not, however, show as great variability as Denver and there is reason to believe that the mesas and lower foothills are still less variable in climate from year to year than Boulder. Thus it comes about that the mesas are more favorable for tree growth than the plains and that except with plants which grow best in fine-grained soil the species of adjacent plains also grow on the mesas. On the other hand, as noted above, certain foothill plants although able to grow on the mesas cannot extend out to the plains which in summer are drier and hotter and in winter colder and probably more windy.

### 3. Distribution of Conifers on the Mesas

By W. W. Robbins and Gideon S. Dodds

**Rock Pine.** *Pinus scopulorum* (Engelm.) Lemmon.—Rock Pine is the dominant conifer of the foothill region. It extends, in fewer numbers, however, into the montane region, occasionally reaching an altitude of 10,000 feet. Its lower limit of altitudinal distribution is found on the mesas where it meets the grassland formation of the plains zone. A careful study has been made of the distribution of the Rock Pines on Long and Horse Mesas and observations have been made on other mesas lying to the south. In every case its general distribution is the same.

There are three well-marked and noticeably different sizes of trees, other than the seedlings, growing on these mesas. Trees intermediate

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between these three sizes are few and scattered. The oldest and largest trees, one hundred and fifty to two hundred years old, are distributed on the higher parts of the mesa top; they are relatively few in number and quite far apart. Those of the next size are eighty to one hundred years old. They are more numerous than the preceding. They occur among the oldest pines and are found growing farther out toward the mesa end, especially along the north crest, and farther down on the north slopes. The smallest pines are between twenty and thirty years of age. There are large stands of these trees in many places. They grow still farther out on the mesa than the preceding groups but they do not extend entirely to the end. The outermost parts of the mesas have sparse growth of small trees of various sizes. On other mesas also the pines fall into well-defined groups, with few trees intermediate in size. Plate II shows two well-marked sizes of pines on a mesa some miles south of the mesas under study. In the mountains higher up, nearer the center of distribution for the Rock Pine, we do not find such well-marked and clear-cut groups of trees but there are trees of all sizes and ages growing together. These clear-cut groups occur only on the mesas where the pine reaches its lower limit of distribution and these groups indicate that the trees there are meeting severer conditions than those farther up; in other words, they are on a tension line and favorable conditions are not met with every growing season.

The distribution of Rock Pine depends not upon the conditions affecting the large, well-established trees, but upon the conditions which the germinating seeds and seedlings encounter. Good cone-producing years are not common. Furthermore, the seed by no means always falls in a place suitable for germination and even if the seed germinates the seedling requires a series of seasons favorable for its growth, or else it will fail to develop to a size that will make it independent of slight changes in the environmental conditions. Seedlings are able to grow better when shaded; however, shade is not an absolute requirement. Thus at long intervals will there be a year in which all of the above conditions will come together. A large stand of pines of the same size and age evidently means that there was a good cone year, followed by a series of years favorable to the germination and growth of

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seedlings. This seems to be the explanation of the three different sizes of trees on the mesas.[1]

By observing the distribution of the pines as shown in Fig. 1, p. 34, it will be noticed that they are more thickly scattered on the north slopes, especially along the north crest. Conditions are more favorable for the growth of pines on the crests than on the other parts of the mesa slope. This is because of the rocky nature of the soil and the consequent scarcity of grass and other vegetation. This enables the seed to reach the bare soil easily.

It is quite noticeable that young seedlings are often found growing at the side of a large rock. This is probably because there is more moisture around the rock than a little distance away. The seedling in such a location receives the run-off from the rock and the shade of the rock prevents rapid evaporation from the ground in which the seedling is growing.

It is a common observance that seedlings are found growing along old roads (See Fig. 4, Plate II). The soil there is bare and free from grass and the seed finds ready access to the soil. Shantz[2] has observed the same in the Pike's Peak mesa region.

There is a greater growth of pines on the north slopes than on the south slopes. This is largely a matter of moisture, especially in its relation to the seedling. The older pine tree has a very extensive root system which renders available the moisture of the deeper layers of soil; the seedling, on the other hand, with its small root system is dependent upon the moisture in the surface layers. On the south slopes, which are exposed to the direct rays of the sun, the surface soil dries out quickly after a rain. Consequently the young seedling growing there does not find a constant supply of water as does the seedling on the north slope.

The question may now be asked why the lower altitudinal limit of distribution of the Rock Pine is on the mesa instead of somewhere else. Why do not the Rock Pines extend farther out on to the plains? The

[1] The fact that the pines are gradually extending outward on the mesas is mentioned by YOUNG, *Bot. Gaz.*, 44: 321–52, 1907, who discusses briefly their distribution on the mesas and foothills.

[2] SHANTZ, H. L., "A Study of the Vegetation of the Mesa Region East of Pike's Peak," *Bot. Gaz.*, 42: 16–47, and 179–207. July and October, 1906.

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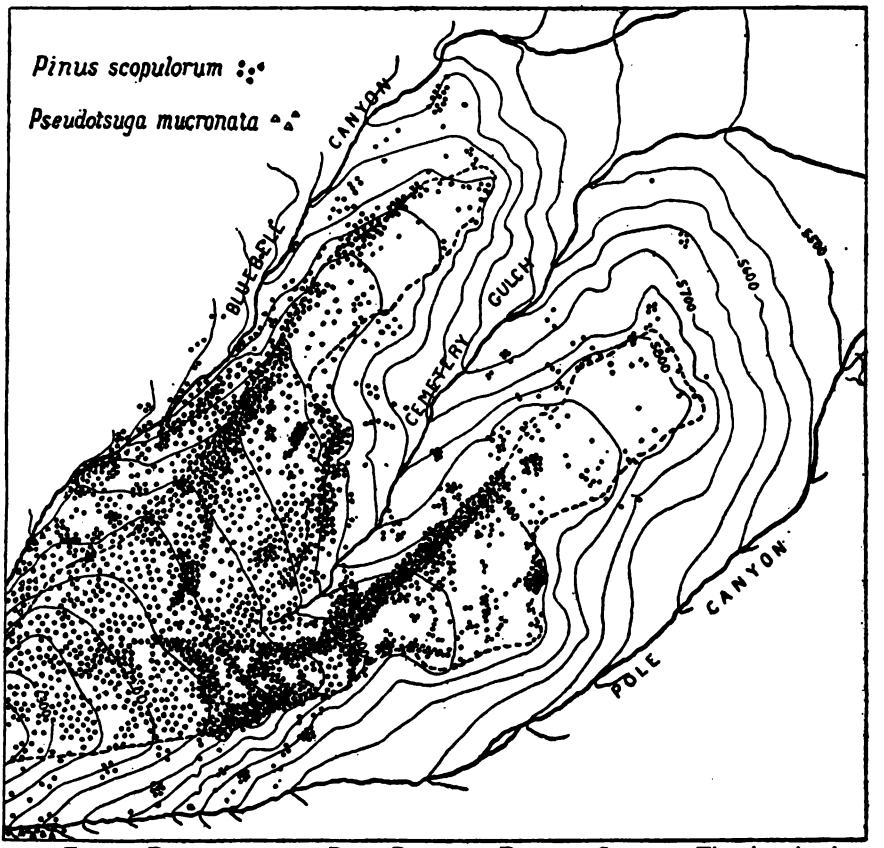


FIG. 1.—DISTRIBUTION OF ROCK PINE AND DOUGLAS SPRUCE.—The dots in the map show the relative frequency of the pines, except in the case of the scattered trees on the east end where individual trees are shown. The more dense growth of trees along the north crests of the mesas is especially noticeable. The south slopes are almost devoid of trees while on the north there is a considerable growth. The trees extend out farther on the north slopes than on the south slopes. The scattered trees shown growing toward the mesa ends are in every case young trees which are invading the grassland. Young trees are also found growing all over the mesas among the older trees. These older trees are more common on the upper part of the mesa top and along the north crests out to a point about half-way to the end of the mesa. On the north slopes the pines are found on the drier parts where the soil is rockier and more devoid of grass. Douglas Spruce grows only in the deeper and moister parts of Bluebell and Pole Canyons, on the north exposures. Cemetery Gulch does not furnish enough shade and moisture for a growth of this tree.

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mesa region is clearly a tension line; conditions here are severer for the pine. From a study of the factors affecting its distribution on the mesas, one may arrive at some conclusions regarding the factors limiting its general distribution. The optimum conditions for the growth of any plant as a rule are found near its center of distribution and most adverse conditions prevail at its limits. At the limits there is an accumulation of adverse conditions, all of which operate to prevent it from extending its range. This is well shown in the case of the Rock Pine.

As seen in the study of distribution on the mesas, moisture is an important factor. The soil is almost too dry for the seedlings to get a start and they can only attain a foothold in the most favorable situations during seasons in which there is unusual rainfall. Farther east on the plains the moisture is still less than it is on the mesas and probably under the most favorable conditions is too little for the growth of the seedling. However, it is sufficient in many places to support a pine of good size with its extensive root system. This is shown by the continued growth of such trees transplanted to the plains regions or of seedlings carried past the danger period under cultivation. Clearly it is the effect of the dryness upon the seedling and not upon the large tree, which prevents further extension of the Rock Pines.

Competition with the grassland formation is another important factor limiting the distribution of the trees. This again has its relation to the seedling and not to the older tree. The fine-grained soil of the plains is adapted to the growth of grass which on the edges of the pine formation prevents the pine seed from reaching the soil. The coarser soil of the mesas, being less favorable for a dense growth of grass, allows the pine to get a foothold in the mesa region. This explains in part the good growth of trees on the top, and especially on the rocky crests of the mesas. Also it accounts for their almost complete absence on the lower parts of the mesa slopes, especially toward the east end, where the fine-grained soil supports a dense growth of grass.

It has been pointed out in the account of the climatology, p. 29, that daily extremes of temperature are considerably greater on the plains than on the mesas. This may be of considerable importance in checking

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the eastward spread of the pine. It is very probable that the seedlings are killed by late frosts.[1]

**Douglas Spruce.** *Pseudotsuga mucronata* (RAF.) SUDW.—This is a tree of the higher foothill region, not extending down to the lower limit of Rock Pine. In the higher altitudes it grows upon hillsides with north exposure, but in the lower foothill region it is confined to the deep, moist gulches. The map (see Fig. 1) indicates its distribution on the mesas. It will be seen that it grows only on the north slope and deeper parts of Pole and Bluebell Canyons.

**Mountain Juniper.** *Juniperus sibirica* BURGSD.—According to Rydberg,[2] this tree or shrub has its lower limit of altitudinal distribution at about 6,500 feet. On these mesas it extends down to about 6,000 feet. A few isolated individuals are found upon the higher parts of the mesas.

**Rocky Mountain Red Cedar.** *Sabina scopulorum* (SARG.) RYDB.—A few individuals of this species are found scattered here and there on the mesa top among the pines. This is a tree which commonly grows in dry situations extending into both lower and higher altitudes.

## 4. DISTRIBUTION OF THE DECIDUOUS TREES AND SHRUBS ON THE MESAS

BY W. W. ROBBINS

The mesa region is an area of transition between plains and foothill forms of vegetation. Plains forms here have their upper limit of distribution and foothill forms their lower limit. A general view of the mesa region and its relation to the plains and foothills is shown in Fig. 1, Plate I. The mesa with an altitudinal range of eight hundred feet, its various exposures, its two bounding gulches of different ages, its lateral ravines, depressions and amphitheaters with their accompanying differences in physical factors, offers a variety of habitats. The vegetation shows a response to these differences in the topography.

The shrubs and deciduous trees on Long Mesa have been mapped

[1] Since the above was written, there has appeared a paper by LEROY HARRIS HARVEY, "Floral Succession in the Prairie-Grass Formation of Southeastern South Dakota," *Bot. Gaz.*, 46:81–109, August, 1908, in which are mentioned the same factors as are considered here, as preventing the invasion of the grassland by the trees.

[2] *Flora of Colo.*, Bull. 100, Colo. Agr. Exp. Sta.

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accurately along with the topography so that the relation between their distribution and the topography can be observed readily by the reader. It is hoped that the maps will show at a glance what pages of description would not indicate. The physiography and soil conditions are

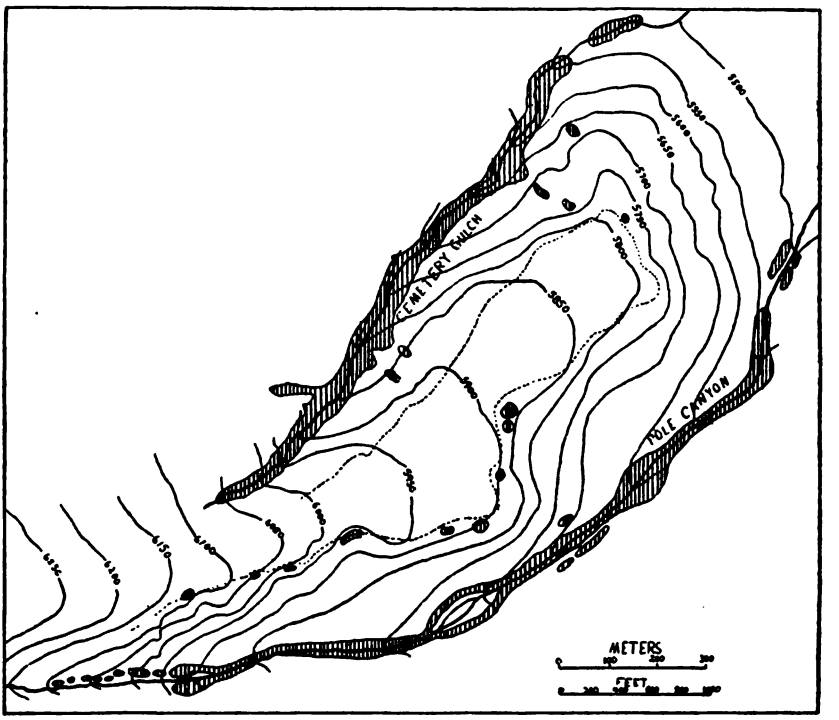


FIG. 1.—THORN APPLE. *Crataegus* spp.—The different species of *Crataegus* are evenly distributed, being the most abundant shrubs or small trees of the gulches. With choke cherries and thimble berries they form impassable growths in some places. Small clumps are getting started in the ravines on the sides of the mesa. In the depressions and amphitheaters on the east and south slopes a good start of *Crataegus* has been made due to seepage water as explained in the text. Here it occurs along with skunk bush, choke cherry and Indian currant.

discussed in the paper by Mr. Dodds and should be kept in mind in considering the distribution of any particular plant.

The careful mapping of the vegetation of an area of limited extent is valuable as throwing light upon plant distribution and the relation

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of plant growth to the topography and its various edaphic factors. Furthermore, such a record of existing conditions can be used for comparison with other areas and in subsequent study of the same area. The latter will be valuable in studying invasion or succession and in finding out the effects of competition.

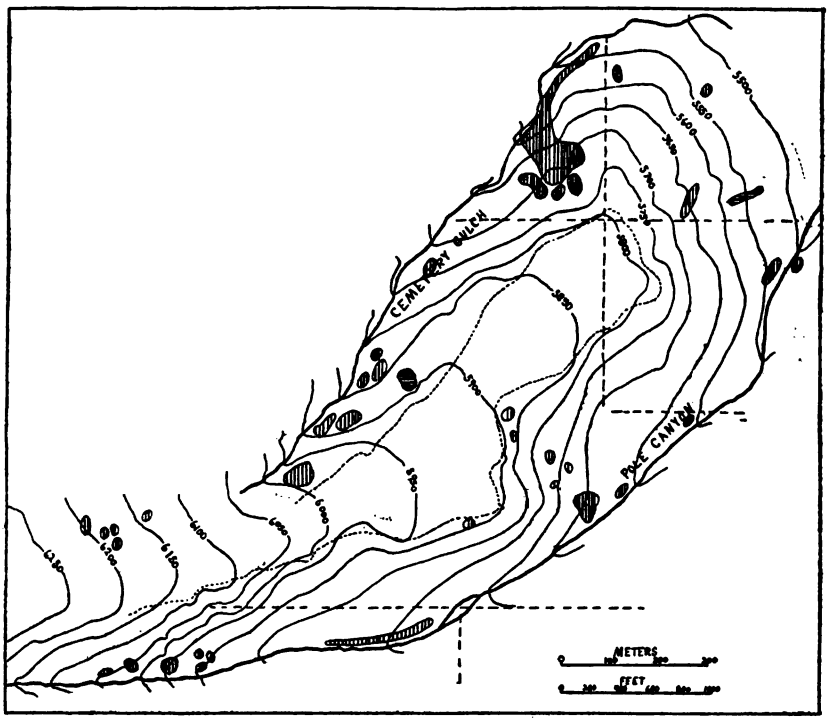


FIG. 2.—INDIAN CURRANT. *Symphoricarpos occidentalis* Hook.—This plant forms one of the prominent societies of the mesa. It reaches its greatest development on the north slopes in moist places, especially in the ravines. Patches are frequent on the expanses back from the streams in both gulches. (See Fig. 2, Plate I.) A few patches occur on the upper part of the mesa top among the older pine trees.

In discussing the distribution of the trees and shrubs of this area, humidity, temperature, wind, light and pressure need not be taken into consideration as being directly effective factors. Water content of the soil seems to be the important factor determining their distribution.

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Altitude, slope, exposure and soil texture influence the distribution only in so far as they affect the water content of the soil.

The accompanying maps indicate the distribution of eighteen of the more important shrubs and deciduous trees growing on Long Mesa.

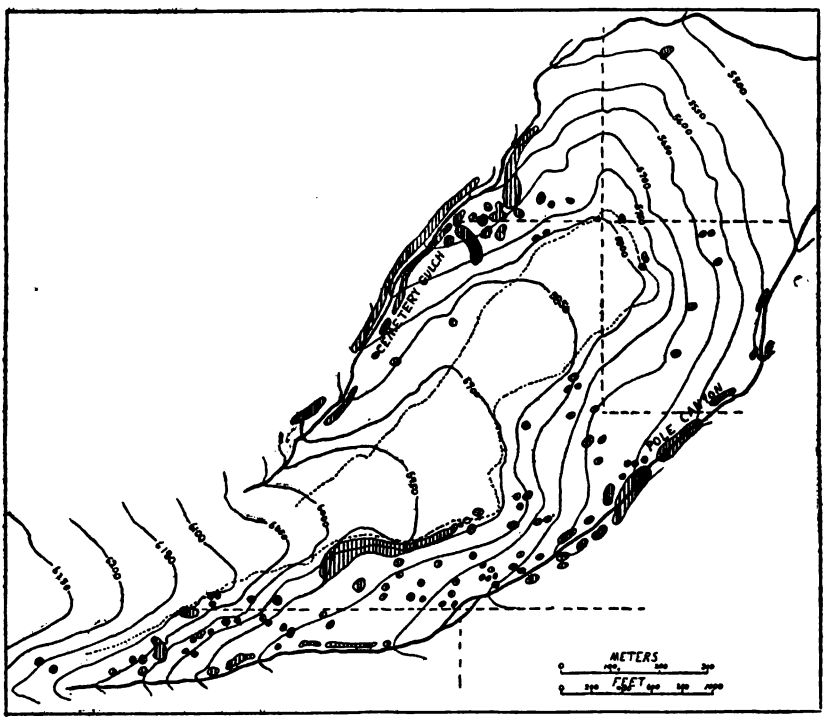


FIG. 3.—SKUNK BUSH. *Rhus trilobata* Nutt.—The most extensive growth of this shrub occurs in the gulches outside the *Crataegus* zone. Almost every depression and amphitheater contains a well-developed mass of skunk bush, growing just below the rock cap. Skunk bush requires a moderate supply of water to support a thick growth; in the depressions and amphitheaters it receives a sufficient quantity by seepage to form quite a dense growth. Isolated bushes are frequent over both slopes growing even in dry places. They show, however, a characteristic response in numbers; the discontinuous distribution is due to the water supply, the shrub being most abundant in moist situations.

The distribution of the less important ones (twenty species) is described but it was not considered worth while to map them. A very similar distribution occurs on Horse Mesa.

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**Currants.** *Ribes longiflorum* Nutt.; *R. pumilum* Nutt.; *R. vallicola* Greene.—The several species grow most abundantly in the gulches. Scattered bushes of *Ribes pumilum* are found on the north slope and in the shade of the pines growing on the north crest of the mesa where,

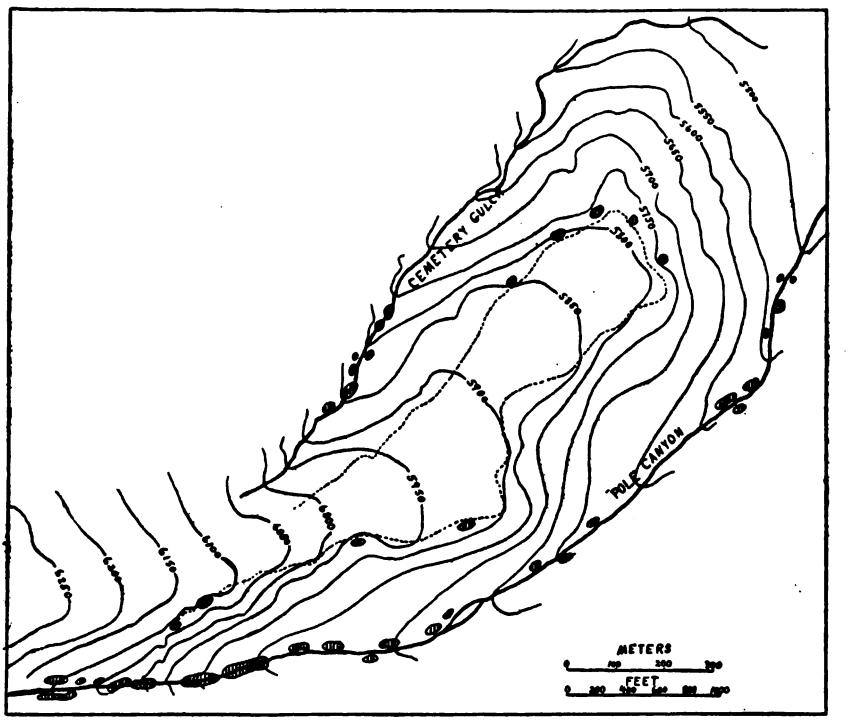


FIG. 4.—CHOKE CHERRY. *Prunus melanocarpa* (A. Nels.) Rydb.—The map indicates that this tree is generally distributed in the gulches. A younger growth occurs in clumps in the depressions, amphitheaters and ravines on both sides of the mesa. In these situations it is found below the hill crest in the seepage zone. (See Fig. 2, p. 14). Isolated trees, one or two years old, occur even in dry and exposed situations. It is probable that these trees started during a series of wet years and were able in that time to develop a root system deep enough to enable them to get the required moisture from the soil.

along with thimble berries, they form small thickets. It is common to find this same species around almost every large pine tree and large

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rock on the top of the mesa. The tree or rock, as the case may be, furnishes shade for the young plant.

**Thimble Berry.** *Rubus deliciosus* James.—This shrub is found in both gulches, especially at the upper parts. Single plants are found on the north slope and in the shade of the largest pine trees on the north crest.

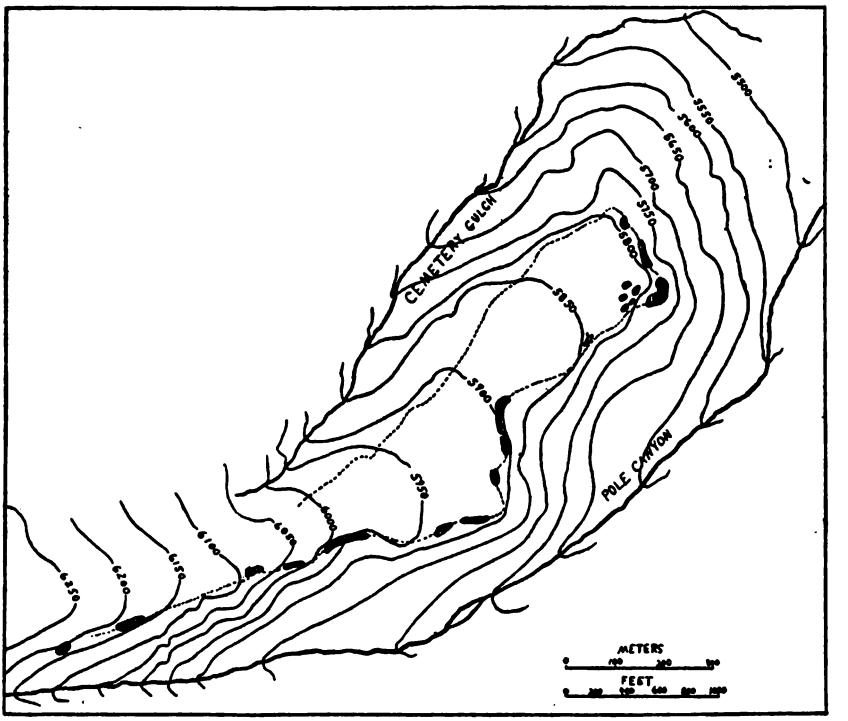


FIG. 5.—NEW JERSEY TEA. *Ceanothus fendleri* A. Gray; *C. pubescens* (T. & G.) Rydb.—Both species are about evenly distributed. They grow on east, southeast and south crests of the mesa in very stony xerophytic habitats. None are found in the gulches, on north exposures nor on the mesa top, except at the extreme east tip, which is very dry.

**June Berry.** *Amelanchier alnifolia* Nutt.—This plant is not abundant. It commonly occupies rather moist situations.

**Nine Bark.** *Opulaster ramaleyi* A. Nels.; *O. glabratus* Rydb.; *O. monogynus* (Torr.) Kuntze.—Of the three species represented, *O. glabratus* and *O. monogynus* are the most common. They are found

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here and there in both gulches, being best developed in shady, moist places. They are also found in the lateral ravines on the north exposure.

**Alder.** *Alnus tenuifolia* Nutt.—The alders grow only in Pole Canyon, being entirely absent from Cemetery Gulch.

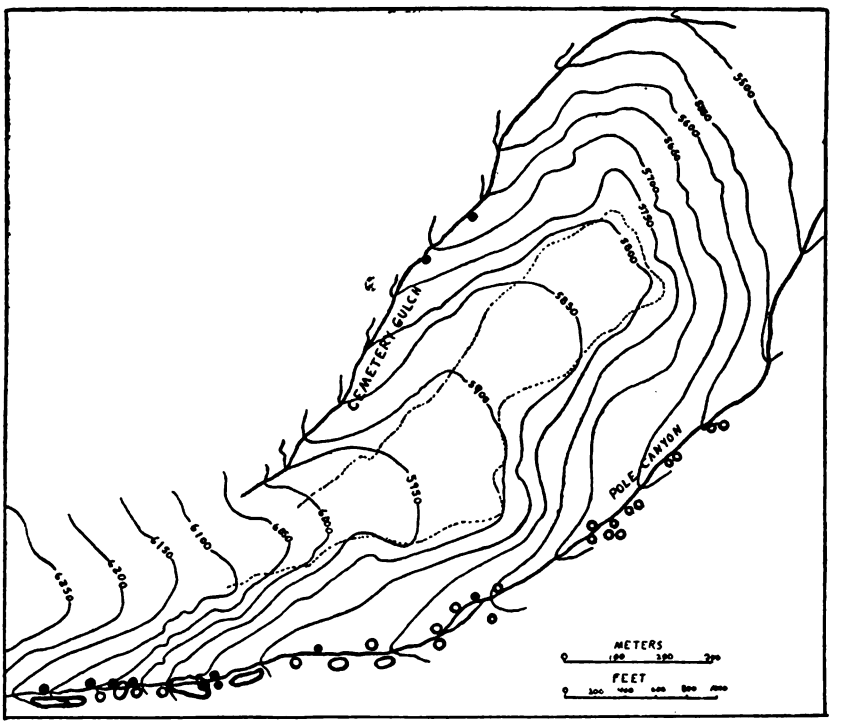


FIG. 6.—BOX ELDER AND MOUNTAIN MAPLE. *Acer negundo* TORR., *A. glabrum* TORR. —In the map box elder is represented by black dots. It is noticed that a greater number of trees occur in Pole Canyon than in Cemetery Gulch. In the latter gulch the two trees are quite young. In the map mountain maple is represented by inclosed areas. It is here confined to Pole Canyon. It is most abundant on the south side of the stream on the north slope. In the mesa region mountain maple grows near the bottom of the gulch. At higher altitudes it is more frequently on steep hillsides. This difference is due to the greater rainfall of the higher altitudes. There, the hillsides are moist enough for the maple, while in the mesa region it must get into the gulches for sufficient water.

**Wax Flower.** *Edwinia americana* (T. & G.) Heller.—This shrub grows only near the head of Bluebell Canyon on the north exposure. It

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is a mountain form and hence is relatively infrequent in this region. Altitude 5,500 to 10,000 ft.

**Poison Ivy.** *Rhus rydbergii* Small.—Only a few plants of this species

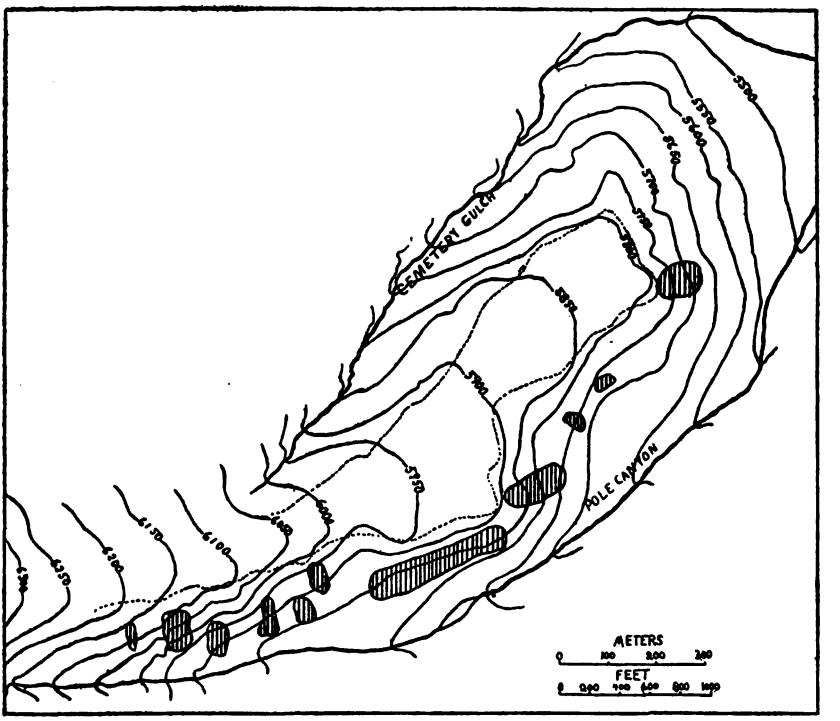


FIG. 7.—SOAPWEED. *Yucca glauca* Nutt.—Yucca is a dry ridge plant. On the mesa its distribution is limited to the ridges on the south and southeast slopes. By comparing the positions and extent of the societies of Yucca with the outcrops of shale as shown in Fig. 4, p. 17, it is strikingly noticeable that where the underlying shale is exposed, there also is a growth of Yucca. It seems from these observations that the presence of shale soil determines the distribution of Yucca. However, according to the observations of Shantz[1] in the Pike's Peak mesa region, Yucca is found occupying a coarse, gravelly soil of low water content. Evidently soil texture does not determine entirely its distribution, for the shale in which it grows here is a fine-grained soil. A fine-grained soil can hold more moisture than a coarse, gravelly soil, but the available water is less. In this region the xerophytic ridges, where Yucca commonly grows, shows exposed shale for the reason that the mesa cap has been eroded off into the ravines between.

[1] SHANTZ, H. L., "A Study of the Vegetation of the Mesa Region East of Pike's Peak," *Bot. Gaz.*, 42: 16–47, and 179–207, July and October, 1906.

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are found in this area. It grows as a rule in rather moist situations, either in the gulches or on mesa slopes and top.

**Kinnikinik.** *Arctostaphylos uva-ursi* (L.) Spreng.—This plant

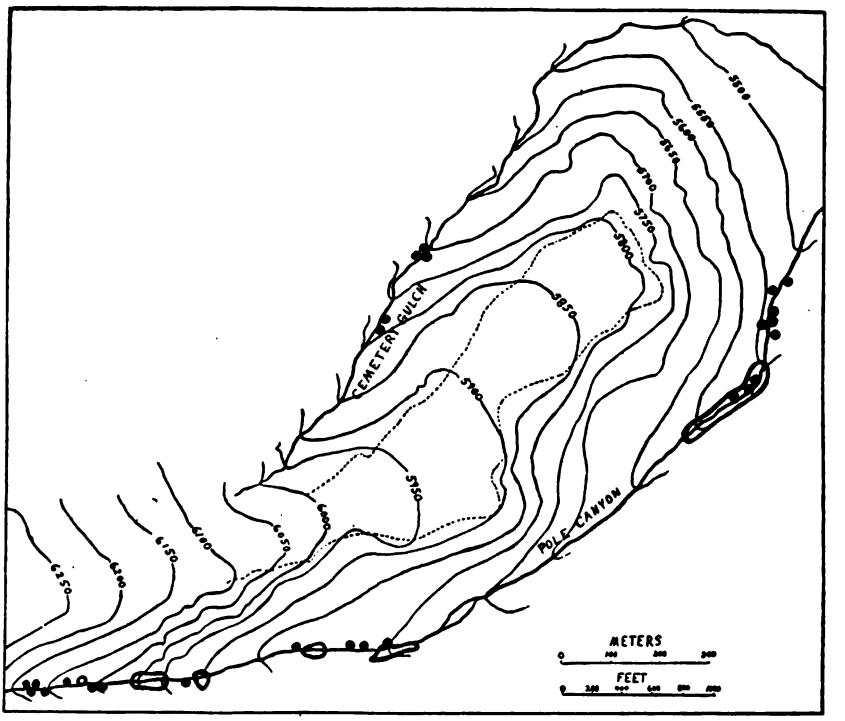


FIG. 8.—COTTONWOODS AND WILLOWS. *Populus angustifolia* James; *Salix amygdaloides* Anders.; *S. exigua* Nutt.—In the map the willows are represented by solid black dots, the cottonwoods by inclosed areas. The cottonwoods and willows are distinctly stream and gulch plants. The narrowleaf cottonwood occurs in Pole Canyon but is not found in Cemetery Gulch. There are also fewer willows in Cemetery Gulch. These differences are accounted for by the fact that the latter gulch is not as old and deep as Pole Canyon and hence does not receive as great an amount of water. The same reason will account for the fact that there are more willows in Pole Canyon than in Cemetery Gulch. The common western cottonwood, *Populus sargentii* Dode, is not found in either gulch. Its distribution in the mountains is more commonly in the deeper canyons whose streams flow out into the plains and connect with larger eastward-flowing streams. Such a distribution indicates that the western cottonwood is more distinctly a plains form than the narrowleaf cottonwood and that it spread to the mountains up the larger water courses which stretched out to the plains.

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reaches its lower limit of altitudinal distribution at about 5,500 ft. and hence is not abundant on the mesa. A few patches occur well toward the upper end of the mesa.

**Wild Plum.** *Prunus americana* Marsh.—A few wild plums are found in both gulches, more occuring in Pole Canyon than in Cemetery

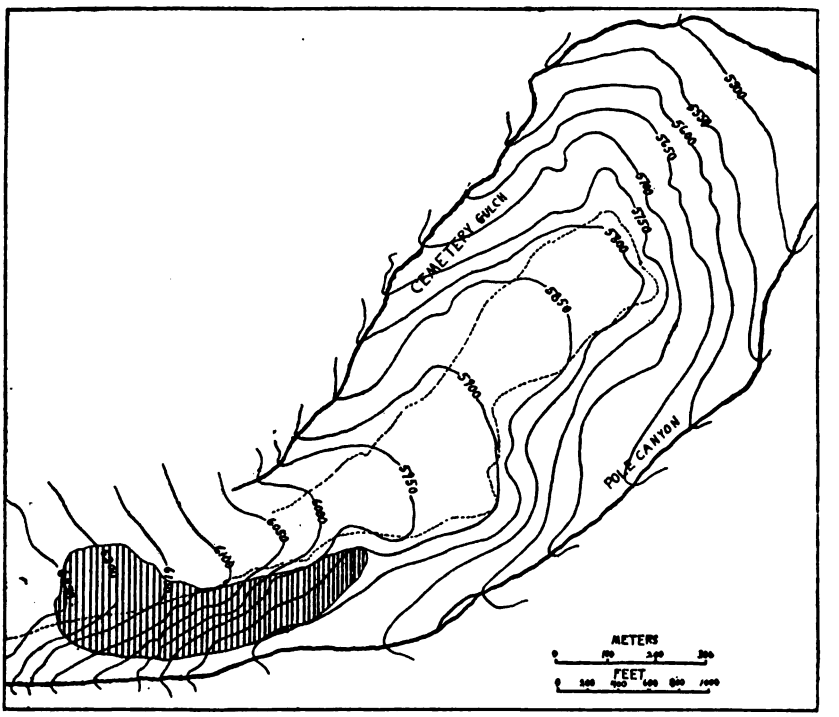


FIG. 9.—OREGON GRAPE. *Berberis repens* Lindl.—This shrub is best developed on the steep south slope at the upper part of the mesa. It is one of the first plants to bloom in the early spring. Many of the early-blooming plants are found growing on the south slopes where they receive the most heat of the sun. Since this plant flowers and develops the fruit in the early spring, which in this area is usually the wettest part of the growing season, it is not so dependent upon the amount of soil moisture during the rest of the season, as are other later-blooming plants of the same habitat. For this reason its distribution on the steep south slopes does not explain its extreme xerophytic nature so much as it does its relation to the time it blooms.

Gulch. Several trees were found growing on north and south exposures in dry soil.

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**Mountain Mahogany.** *Cercocarpus parvifolius* Nutt.—One specimen of this shrub is found on Long Mesa, on the south crest toward the top. On Horse Mesa, however, it forms an extensive society on the north crest extending on to the top and down on the north slope. Exactly similar habitats may be found on Long Mesa and it is only a matter of chance distribution that it is not found there.

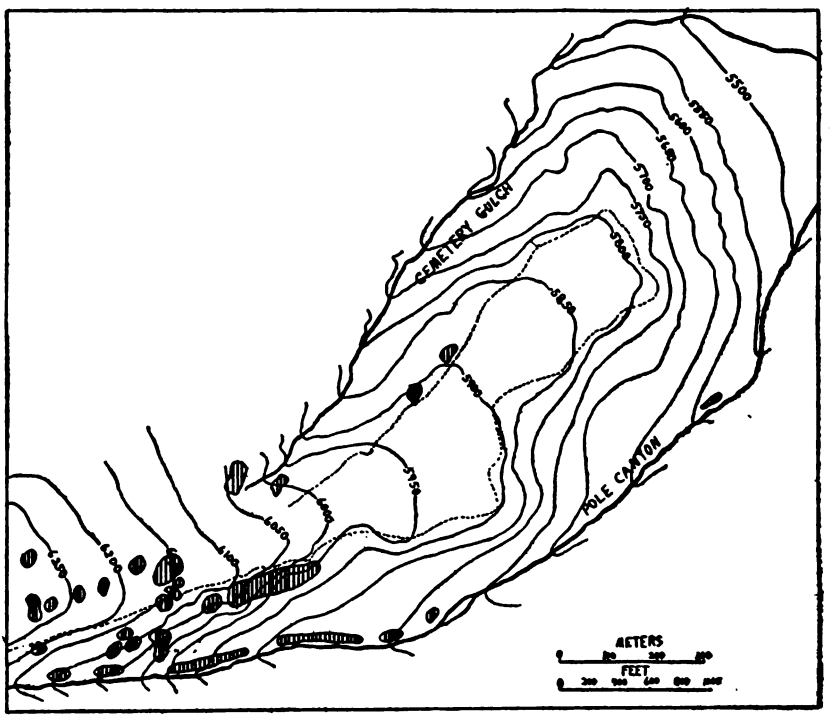


FIG. 10.—SUMAC. *Rhus glabra* L.—Sumac reaches its maximum development on the south exposure at the upper part of the mesa. Here it dominates large areas, occurring in stony soil. Masses of the shrub are found in the open places among the pines on the upper part of the mesa top. In Pole Canyon it occurs just outside the *Crataegus* zone in drier soil. None occurs in Cemetery Gulch. Sumac seems able to grow in habitats having very different physical factors. Its discontinuous distribution is probably due to competition rather than to differences in the physical conditions.

**Roses.** *Rosa sayi* Schwein.; *R. fendleri* Crepin; *R. nutkana* Presl.; *R. pratincola* Greene.—The roses form a layer underneath the *Crataegus*.

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*Rosa sayi* covers quite extensive areas on the east and southeast slopes; on these slopes it grows as abundantly in the depressions as on the drier ridges separating them. The roses are also quite common in the pine shade on the upper mesa top.

**Birch.** *Betula fontinalis* Sarg.—One tree grows in the upper part of Pole Canyon.

**Hackberry.** *Celtis reticulata* Torr.—One tree is found at the lower end of Cemetery Gulch.

## Summary

The mesa sides are cut by lateral ravines of various depths. These ravines on the north slope are narrow and some extend to the mesa top; those on the east and south sides as a rule take the form of amphitheaters or depressions. In all cases the ravines, amphitheaters and depressions receive seepage water from the top and sides and are more mesophytic than the ridges between. In these moister places one may find shrubs common to the main gulches, such as skunk bush, nine bark, choke cherry, roses, currants and thorn apples. On the north slope Indian currant is generally the first shrub to find its way into an embryonic ravine. It is followed by roses, currants and skunk bush; while nine bark, choke cherry and thorn apple come in after the ravine has deepened and the topography become more favorable for the collection and conservation of moisture. As a final stage thorn apple will dominate. With the deepening of the gulch such deciduous trees as narrowleaf cottonwood, willow, alder, birch and mountain maple will come in.

In the amphitheaters the shrubs grow just below the rock cap. It is quite evident that their distribution there is due to the fact that they receive seepage water which has followed along on the more impervious shale, which underlies the rock cap. (See p. 18.) Looking at the mesa from a distance a fringe of shrubs just below the edge is quite noticeable.

The shrubs of the mesa are easily divisible, in most cases, into mesophytes and xerophytes. Mesophytic shrubs occur in the gulches, small ravines, depressions and seepage zone of the amphitheaters. They include nine bark, thorn apple, thimble berry, poison ivy, Indian currant,

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currants and roses. The xerophytic shrubs are common on the crests and top of the mesa; they include Oregon grape, New Jersey tea and *Rosa sayi*. Skunk bush and sumac are found growing in both mesophytic and xerophytic places. There is a noticeable absence of shrubs on the mesa top. With the exception of sumac and Indian currant, those shrubs which do occur there are almost always found in the shade of the pine trees. Such shade-seeking shrubs are *Ribes pumilum*, thimble berry and roses. In the open on the mesa top, grass is a successful competitor and excludes the shrubs, while in tthe shade of the pines, not only is there less grass on account of the shade, but a somewhat moister soil on account of the same condition, and hence shrubs find it easier to get a start.

As a rule the relative ages of topographic forms can be determined by a comparison of their vegetative covering. A good example of this is to be found in comparing the deciduous tree growth of Pole Canyon with that of Cemetery Gulch. It is seen that the number of willows, cottonwoods, box elders, maples, choke cherries and wild plums is far greater in Pole Canyon than in Cemetery Gulch. Furthermore, birches and alders are entirely absent from the latter gulch. This condition is due to a greater water supply in Pole Canyon, which in turn indicates that it must be deeper and older than Cemetery Gulch. Such comparisons, however, are frequently of no consequence. In some cases topographic changes occur so rapidly, with their accompanying rapid changes in the habitats, that the ecological successions are not able to keep pace.

### Explanation of Plates

Fig. 1.—General view of Long and Horse Mesas looking south from roof of a University building. Long Mesa extends farther out to the east; only the eastern part of Horse Mesa is shown. The even and gentle slope of these mesas is very characteristic. It is seen that trees are present only on the portions nearer the foothills. The dark areas on Long Mesa are formed by shrubs, chiefly Indian currants, in the ravines and depressions.

Fig. 2.—A view looking up Cemetary Gulch toward the foothills. Horse Mesa is on the right, Long Mesa on the left. The pointed mountain in the center of background is South Boulder Peak (alt. 8,460 ft.). Pine trees extend out along the north crest of Long Mesa. In the gulch there is a thick growth of thorn apple, choke cherry, skunk bush, nine bark and thimble berry. The thorn apples form, however, the most abundant growth in the gulch. The dark patches of vegetation on the north slope of Long Mesa

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are mostly Indian currant. The small lateral ravines on the south slope of Horse Mesa support chiefly a growth of young thorn apple, choke cherry and skunk bush.

FIG. 3.—Invasion of grassland by rock pines. The coarseness of the soil is indicated by the numerous boulders. It is in such situations as this that young pines are able to become established while it would be much more difficult in the fine-grained soil of the plains.

FIG. 4.—The view shows numerous rock pine seedlings getting started along a road on the mesa. Seedlings are common along old road beds and other places where the ground is bare.

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PLATE I

FIG. 1

FIG. 2
VEGETATION OF THE MESAS NEAR BOULDER, COLO.

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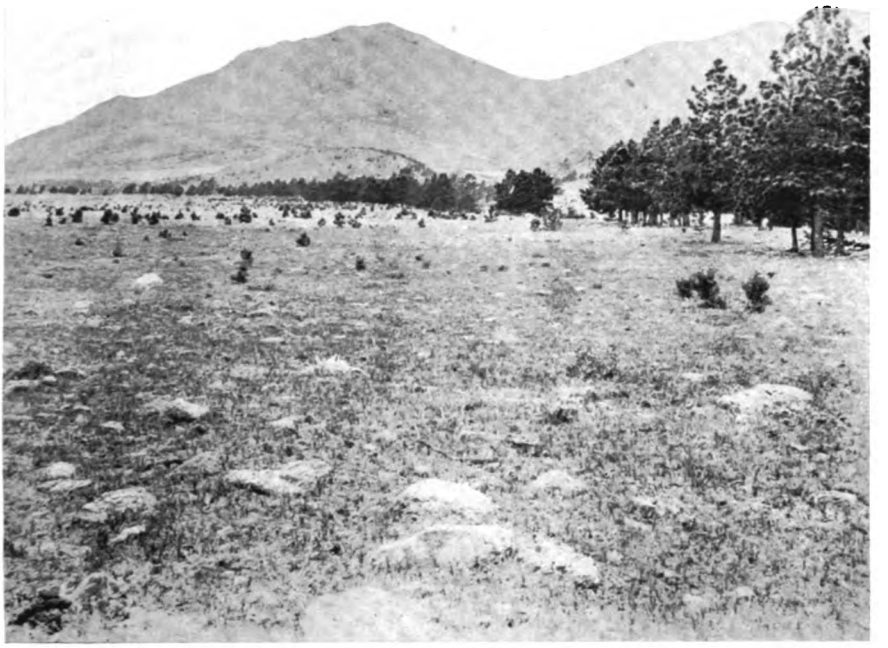

FIG. 3

FIG. 4
VEGETATION OF THE MESAS NEAR BOULDER, COLO.

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# BIBLIOGRAPHY AND HISTORY OF COLORADO BOTANY

By Miss Edith M. Allison

Some time ago work was begun by members of the biological staff on a bibliography of Colorado botany and about one-fourth of the titles were listed in a card catalogue. The work of preparing the present paper consisted in looking through the various botanical journals and geological reports and incorporating this new material with what had been done before.

It has been the object to cover as far as possible all work on the seed plants of Colorado but the bibliography is necessarily incomplete as records of certain pieces of work could not be obtained. Such papers on fungi and other lower plants as were easily found have been listed but no special search was made for these. General botanical works, although referring to plants in Colorado, have not been listed, e. g., Gray's *Manual*, Britton and Brown's *Flora*, etc. The list includes such papers on geology and climatology as naturally bear on the subject. The names of collectors and those who have engaged in field study of ecology are listed with a brief statement of the work they have done. Bold-faced type is used for their names while capitals and small capitals are used for the names of authors.[1]

In compiling the bibliography the author is indebted to Messrs. Francis Ramaley, University of Colo.; T. D. A. Cockerell, University of Colo.; Aven Nelson, University of Wyoming; F. S. Earle, Henadura, Cuba; L. H. Pammel, Iowa State College of Agriculture; Marcus E. Jones, Salt Lake City, Utah; Carl F. Baker, Pomona College, Claremont, Calif.; John M. Coulter, University of Chicago; Ellsworth Bethel, East Side High School, Denver Colo.; F. H. Brandenburg, Denver, Colo.; Edward L. Greene, Smithsonian Institution, United States National Museum, Washington, D. C.; Frederic E. Clements, University

[1] The editor of these *Studies* will be pleased to receive any additions or corrections to the list of botanists and of botanical papers here printed. Such additions can be published later in a supplementary list.



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of Minnesota, Minneapolis, Minn.; George E. Osterhout, New Windsor, Colo.; James Cosmo Melvill, Shrewsbury, England; William S. Cooper, University of Chicago; P. A. Rydberg, New York Botanical Garden, Bronx Park, New York City; T. S. Brandegee, Berkeley, Calif.; William Trelease, Missouri Botanical Garden, St. Louis, Mo.; C. S. Crandall, University of Illinois, College of Agriculture; John M. Holzinger, Winona, Minn.; W. C. Sturgis, Colorado School of Forestry; E. Penard, Geneva, Switzerland; Dr. Charles Denison, Denver, Colo.; Dr. Carroll E. Edson, Denver, Colo.; Miss Alice Eastwood, San Francisco, Calif., who have contributed imformation regarding their work done in Colorado. Further thanks are due Professor Francis Ramaley who has kindly supervised the work.

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**Andrews, Darwin M.** Has made collections in the vicinity of Boulder, and elsewhere in northern Colorado, beginning in 1893. Specimens sent for identification to Professor Aven Nelson. Address: Boulder, Colo.

ANGELL, CHESTER M., "Colorado Springs Weather Records between 1872 and 1903," *Colo. College Pub., Sci. Ser. 47–49, Gen. Ser. 23*, Vol. XII, pp. 306–18.

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**Archibald, Jennie M.** (Mrs. J. C. Blake). Collected plants at Berwind in 1900, the specimens being all sent to University of Colorado Herbarium. Among other new species collected the most interesting one is *Polemonium archibaldae* Aven Nelson.

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AUSTIN, C. F., "New Mosses from Colorado," *Bull. Torr. Bot. Club*, Vol. VI, pp. 45–46, 1875. [Two new species described.]

**Baker, Carl F.** Made collections in southern and western Colorado in the years 1896, 1898, 1899, 1901. Specimens sent to Dr. E. L. Greene for study; new species published by Greene in *Plantae Bakerianae. Exsiccati* sent to principal herbaria.

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BAKER, CARL F. (author with Greene, E. L., and Earle, F. S., which see). Contributed the narrative accounts of Greene's *Plantae Bakerianae*.

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**Beecher, Miss Ella,** formerly of Monument, Colo. Made collections at Colorado Springs and near Monument, Colo. (This information was kindly supplied by Mr. Marcus E. Jones.)

**Bell, W. A.** Collected in 1867 near Pike's Peak and elsewhere. *Fide* Porter.

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**Bessey, Ernst A.** Made collections in vicinity of Colorado Springs and Pike's Peak 1894–95–96 and again in 1899.

**Bethel, Ellsworth.** Collections, chiefly fungi, made in various parts of the state. Many specimens sent to eastern botanists for determination and study. Now preparing for publication an account of the Gymnosporangiums and of the trees of Colorado. Mr. Bethel has a very large private herbarium. Address: East Denver High School, Denver, Colo.

BICKNELL, EUGENE P., "Studies in Sisyrinchium, IV," *Bull. Torr. Bot. Club*, Vol. XXVI, pp. 445–57. [Two new species collected in Colorado described.]

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**Blumer, J. C.** Collected in Park County and elsewhere in 1903.

**Brandegee, T. S.** Collected in 1871 and as late as 1881, in Fremont and Gunnison counties. Fremont County plants were sent to J. H. Redfield who referred the doubtful ones to Dr. Asa Gray. Mosses and algae were sent to Eugene Rau and lichens to Charles James Sprague. Mr. Brandegee also collected woods for Sargent for his centennial report and for the Jesup Collection.

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**Brandenburg, Frederick H.** Since 1882 in the weather service in Colorado. District forecaster and director of Colorado climatological service since 1894. Has published various items and articles in the *Monthly Weather Review* and in the bulletins of the *Climatological Service*. Address: Denver, Colo.

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**Canby, W. M.** Collected in 1871. *Fide* Porter.

**Cannon, Geo. L.** Made botanical studies and collections in different parts of the state since 1878. Address: East Denver High School, Denver, Colo.

CARDOT, J. (joint author with Renauld, F., which see).

CARDOT, J., AND THÉRIOT, I., "New or Unrecorded Mosses of North America," *Bot. Gazette*, Vol. XXXVII, pp. 363–82, 1904. [A number of species were collected in Colorado.]

**Carpenter, L. G.** Director of experiment station, Colorado Agricultural College. Has made extended studies of meteorology during his connection with the college. Address: Ft. Collins, Colo.

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**Cassidy, James.** Collected in Colorado while professor of botany and horticulture at Colorado Agricultural College 1882–90.

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**Clements, Edith Schwartz** (Mrs. F. E. Clements). Made collections and ecological studies in the Pike's Peak region from 1899 to 1908. Contributed to the sets of *exsiccati* distributed by F. E. Clements.

CLEMENTS, EDITH SCHWARTZ, "The Relation of Leaf Structure to Physical Factors," *Trans. Amer. Mic. Soc.*, pp. 19–102 (no date.) [Work done at Minnehaha, Colo.]

**Clements, Frederic E.** Spent summers since 1896 in Pikes' Peak region making ecological studies. Has distributed various *exsiccati*. In 1907 a large number of places in the state were visited. In 1908 Long's Peak and Estes Park were studied.

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*Climatological Service of the Weather Bureau,* Colo. Section. [Issues a monthly report and an annual summary dealing with the climatology of Colorado under the following heads: temperature, precipitation, sunshine, cloudiness, wind, relative humidity, etc. In June, 1908, there were 88 stations in this state recording temperatures and precipitation.]

**Cockerell, T. D. A.** Collected in Wet Mountain Valley 1887–90. Specimens were sent to Kew and to other herbaria. More recent collections near Boulder. Address: University of Colorado, Boulder, Colo.

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COCKERELL, T. D. A. AND W. P., "The Colorado Rubber Plant," *Frontier*, pp. 315, 316, April, 1904.

COCKERELL, W. P., "Note on a Rubber Producing Plant," *Science*, Vol. XIX, pp. 314, 315, 1904.

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**Cooper, William S.** Collected plants in the vicinity of Long's Peak and Estes Park in 1904, 1906 and 1908. The specimens were sent to Professor Aven Nelson. Ecological studies were also made.

COOPER, WILLIAM S., "The Wild Flowers of Estes Park," in Mills' *Story of Estes Park*, Denver, 1905. [This is a five-page popular account of the most conspicuous wild plants of Estes Park, Colo.]

———, "Alpine Vegetation in the Vicinity of Long's Peak, Colorado," *Bot. Gazette*, Vol. XLV, pp. 319–37, 1908. [An ecological paper illustrated with photographs of physiography and wind timber.]

**Coulter, John M.** Collected in 1873. Was with Hayden Survey.

COULTER, JOHN M., *Manual of Botany. (Phaenogamia and Pteridophyta) of the Rocky Mountain Region.* New York: American Book Co. No date. Pp. 453. [This well-known manual is often bound together with Gray's *Lessons in Botany* and called Gray and Coulter's *Text-book of Western Botany.*]

———, "Preliminary Revision of the North American Species of *Cactus*, *Anhalonium*, and *Lophophora*," *Contributions from U. S. National Herbarium*, Vol. III, pp. 95–132, 1894. [Including specimens from Colorado.]

———, "Preliminary Revision of the North American Species of *Echinocactus*, *Cereus* and *Opuntia*," *Contributions from U. S. National Herbarium*, Vol. III, pp. 357–462, 1896. [Includes some Colorado specimens.]

COULTER, JOHN M., AND FISHER, E. M., "Some New North American Plants," *Bot. Gazette*, Vol. XVII, p. 349, 1892. [*Abronia carletoni* from eastern Colorado.]

COULTER, JOHN M. (joint author with Porter, Thomas C., which see).

COULTER, JOHN M., AND ROSE, J. N., "Monograph of the North American Umbelliferae," *Contributions from U. S. National Herbarium*, Vol. VII, No. I, pp. 9–256, 1900. [A number of species were collected in Colorado.]

———, "Synopsis of North American Pines," *Bot. Gazette*, Vol. XI, pp. 256–62, also pp. 302–9, 1886.

COVILLE, FREDERICK V., "*Ribes coloradense*, an Undescribed Currant from the Rocky Mountains of Colo.," *Proc. Biol. Soc. of Washington*, Vol. XIV, pp. 1–6, 1901.

**Cowan, J. H.** Collected near Ft. Collins, at Delta and elsewhere 1891–95; some collections dated 1901.

**Crandall, C. S.** Made collections in various parts of the state while professor in the State Agricultural College at Ft. Collins 1890–99. Most of the specimens were taken from the region around Ft. Collins but other collections were made in 1892 at Alamosa, Antonito in the San Luis Valley, Durango, Silverton, Dolores, Ouray. Gray's Peak, Steamboat Springs, Glenwood, Trapper's Lake and Grand Junction were also visited at other times.

CRANDALL, CHARLES S., "Colorado Weeds," *Bull. No. 23, Colo. Agricultural College Exper. Sta.*, pp. 1–12, 1893.

———, "The Russian Thistle," *Bull. No. 28, Colo. Agricultural College Exper. Sta.*, pp. 1–13, 1894.

———, "Blight and Other Plant Diseases," *Bull. No. 41, Colo. Agricultural College Exper. Sta.*, pp. 1–21, 1898.

CRAWFORD, ALBERT C., "Laboratory Work on Loco Weed Investigation," *Bureau of Plant Industry Bull. 121*, Part III, 1908. [This was carried on in connection with

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work by C. Dwight Marsh whose feeding experiments were done at Hugo, Colo. Author claims that "loco" is due to barium poisoning.]

**Cusack, Mrs. M. E.** Collected in Wet Mountain Valley 1888–90. Her collections sent to Kew Gardens. The duplicates went to Oxford University. *Rosa aciculata* Ckll. described from her collections. Type now in Kew Herbarium.

CUSHMAN, JOSEPH A., "Desmids from Southwestern Colorado," *Bull. Torr. Bot. Club*, Vol. XXXI, pp. 161–65, 1904.

**Daniels, Francis.** Collected in Boulder Co. 1906. Specimens sent to University of Missouri and in his own private herbarium.

DARTON, N. H., *Geology and Underground Waters of the Arkansas Valley in Eastern Colo., Prof. Paper No. 52, Series Descriptive Geol. 89*, Wash. D. C., 1906. [This book contains twenty-eight plates illustrating the drainage, geological formation and vegetation of various places in eastern Colorado.]

**Demetrio, Rev. C. H.** Collected fungi near Sierra Blanca which were sent to Ellis.

DENISON, CHARLES, "Symposium of Climatology, 1895," *Colo. Climatologist*, 1895.

**Diehl, I. E.** Made numerous collections in Colorado chiefly at Farmington. His specimens are in the private herbarium of Marcus E. Jones, Salt Lake City, Utah.

**Dodds, Gideon S.** Made collections of herbarium specimens for University of Colorado in Larimer and Weld counties in 1906 while instructor in the University of Colorado. An account of his collections made near Pawnee Buttes is given by Francis Ramaley in *Univ. of Colo. Studies*, Vol. IV, pp. 161–65, 1907. Alpine plants collected in Boulder and Gilpin counties 1907–1908. Address: Univ. of Pennsylvania, Philadelphia, Penn.

DODDS, GIDEON S., "Scientific Expedition to Northeastern Colorado—General Account," *Univ. of Colo. Studies*, Vol. IV, pp. 145–49, 1907. [This paper deals chiefly with topography and climatology of eastern Weld County with some references to botanical features.]

———, "Studies of Mesa and Foothill Vegetation; 1. Geology and Physiography of the Mesas," *Univ. of Colo. Studies*, Vol. VI, pp. 11–19, 1908. [The mesas south of Boulder are fully described with the help of maps, diagrams and photographs.]

DODDS, G. S., AND ROBBINS, W. W., "Studies of Mesa and Foothill Vegetation; 3. Distribution of Conifers on the Mesas," *Univ. of Colo. Studies*, Vol. VI, pp. 31–36, 1908. [Limits of distribution of pine and Douglas spruce on the mesas south of Boulder. Maps, charts and photographs.]

**Earle, F. S.** Collected in June and July 1898 with C. F. Baker and S. M. Tracy at Mancos, Durango and in the La Plata Mountains.

EARLE, F. S., "Fungi" [from southwestern Colorado and New Mexico], *Plantae Bakerianae*, Vol. II, pp. 1–30, 1901.

——— (author with Greene, E. L., and Baker C. F., which see).

——— (author with Greene, E. L. and Tracy, S. M., which see).

**Eastwood, Miss Alice.** Collected in Colorado 1888 to 1892 chiefly in the central, southern and western counties. Besides the following Miss Eastwood has published papers referring to Colorado botany in the *Proceedings of the California Academy of Science, Zoe*, etc., not seen by the compiler of this bibliography.

EASTWOOD, ALICE, *A Popular Flora of Denver, Colo.* Pamphlet. Pp. 57. San Francisco. No date.

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EASTWOOD, ALICE, "Flora" (in Bergen's *Elements of Botany*). Boston: Ginn & Co.

———, "New Western Plants: New Species from Colorado and Utah," *Bull. Torr. Bot. Club*, Vol. XXIX, pp. 523–25, 1902.

———, "New Species of Western Plants," *Bull. Torr. Bot. Club*, Vol. XXXII, pp. 193–218, 1905. [A new species from Colorado described.]

EATON, D. C., "Ferns of the Southwest," *U. S. Geol. Report*, Vol. VI (*Wheeler Survey*), pp. 299–340. [Ferns of Colorado have been collected by Dr. Parry and Messrs. Hall and Harbour in 1861–64, by Dr. George Vasey in 1868, by Professor John Wolf in 1873 and by Mr. T. S. Brandegee.]

EDSON, CARROLL E., "Notes upon Denver Weather," *Boston Medical and Surgical Journal*, November 18, 1897. [Intended primarily for physicians but useful to botanists.]

———, "A Meteorological Study of the Winter of 1903–04," *Boston Med. and Surg. Journ.*, Vol. CLI, pp. 92–97, 1904.

———, "Denver," in Wood's *Handbook of the Medical Sciences*, Vol. III, pp. 408–11, 1901.

ELLIS AND EVERHART, *Proc. Acad. Nat. Sci. Phila.*, 1893, p. 152. [*Puccinia gutierreziae*, n. sp., Colorado.]

———, *Journal of Mycology*, 1890, p. 119. [Describes new species from Colorado.]

———, "North American Fungi." [A collection of *exsiccati* including, among others, numerous specimens from Colorado.]

ENGELMANN, GEORGE. [Assisted J. T. Rothrock in making a catalogue of plants collected in Nevada, Utah, Colorado, New Mexico and Arizona.] *U. S. Geol. Report of the Territories*, Vol. VI (*Wheeler Survey*), pp. 53–352.

ENSIGN, EDGAR T., "Report of Forest Conditions of the Rocky Mountains," *Depart. Agriculture, Forestry Division, Bull. No. 2*, 2d ed., pp. 141–53, 1889.

FINK, BRUCE, "A Round Trip between Iowa and Puget Sound," *Plant World*, Vol. X, pp. 49–58, 1907. [Describes certain vegetation features at Pueblo, Colorado Springs, etc.]

FISHER, E. M. (joint author with Coulter, John M., which see).

**Fremont's Expeditions**. A series of expeditions to the Rocky Mountains in charge of John C. Fremont, Lieutenant of Engineers in the U. S. Army. The purpose of the first expedition (1842) was to discover a shorter and better route to the Oregon country. No discoveries of any importance were made in Colorado. The second expedition (1843) visited northwestern part of the state, measured the elevation of Ute Pass and Pike's Peak and made botanical collections. Third expedition (1845) did not involve any very important work in Colorado.

GANDOGER, MICHEL, "Flore genus *Eriogonum*," *Bull. Soc. Roy. Bot. Belgique*, July 10, 1906. [Certain new species from Colorado.]

GANNETT, HENRY, "The Forests of the United States," *19th Ann. Report of U. S. Geol. Survey*, Part V, pp. 1–26, 1897–98. (Charles D. Walcott, director.) [Pp. 11, 14, 21, 22, 23, 24 and 25 deal with Colorado.]

———, "The Forest of the United States," *20th Ann. Report of U. S. Geol. Survey*, Part V, pp. 1–38, 1898–99. (Charles D. Walcott, director.) [Pp. 1–9 deal with Colorado reserves.]

———, "Summary of Forestry Work in 1899–1900," *21st Ann. Report of U. S. Geol. Survey*, Part V, pp. 13–15, 1899–1900. (Charles D. Walcott, director.)

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**Gray, Asa.** Collected in Colorado with Joseph Hooker in 1877.

GRAY, ASA, Botanical Notices—T. L. Brandegee: "Flora of Southwestern Colo.," *Amer. Journ. Sci.*, Ser. III, Vol. XII, pp. 232–35.

———, Botanical Notices, "Hall and Harbour's Rocky Mountain Plants," *Amer. Journ. Sci.*, Ser. II, Vol. XXXVI, pp. 128–39.

———, "Enumeration of the Plants of Dr. Parry's Collection in the Rocky Mountains in 1861," *Amer. Journ. Sci.*, Ser. II, Vol. XXXIII, pp. 237–43; 404–11; Vol. XXXIV, pp. 249–61; 330–41.

———, "Enumeration of the Species of Plants Collected by Dr. C. C. Parry and Messrs. Elihu Hall and J. P. Harbour, during the Summer and Autumn of 1862, on and near the Rocky Mountains, in Colorado Territory, lat. 36°–41°," *Proc. Philad. Acad. Nat. Sci.*, pp. 55–80, 1863.

———, "Classification of Botanical Collections Made during the San Juan Reconnaissance of 1877 in Colorado and New Mexico," *Annual Report of Chief of Engineers*, 1878, Appendix SS, pp. 1833–40.

——— (joint author with Torrey, John, which see).

GRAY, ASA, AND HOOKER, JOSEPH, "The Vegetation of the Rocky Mountain Region and a Comparison with That of Other Parts of the World," *Bull. U. S. Geol. and Geog. Survey of the Territories* (*Hayden Survey*), Vol. VI, pp. 1–77.

GREELY, A. W., "Meteorological Observations Made in the State of Colorado," Appendix No. 45, pp. 23–55, *51st Congress Ex. Doc. Report on Climate of Colo. and Utah*, 1891. [This gives all official records up to 1891.]

———, "Report on the Climatology of the Arid Regions of the U. S. with Reference to Irrigation," *51st Congress Ex. Doc.*, Wash., 1891, pp. 5–22. [On p. 16 reference is made to Colorado.]

**Greene, Edward L.** Collected in 1870 to 1873 and at various later dates visiting nearly all parts of the state. Specimens in his own private herbarium and elsewhere.

GREENE, EDWARD L., *Amer. Naturalist*, Vol. VI, p. 76 and p. 734, 1872. [Articles on Colorado botany.]

———, "Studies in the Botany of California and Parts Adjacent," *Bull. Calif. Acad. Sci.*, Vols. I and II, 1885–87. [In these six papers there are various references to Colorado botany.]

———, "Some American Polemoniaceae," *Pittonia*, Vol. I, pp. 120–39, 1887–89. [A few Colorado species.]

———, "New or Noteworthy Species," *Pittonia*, Vol. II, pp. 69–81; 161–73, 1889–92. [Certain species from Colorado.]

———, "New or Noteworthy Species," *Pittonia*, Vol. III, pp. 13–28; 91–116; 154–73; 212–31; 246–53; 257–64; 343–49, 1896–98. [A number of species from Colorado.]

———, "Studies in Compositae," *Pittonia*, Vol. III, pp. 43–63; 146–49; 264–98, 1896–98. [Certain Colorado species.]

———, "Studies in Cruciferae, I," *Pittonia*, Vol. III, pp. 117–38. [A few Colorado species.]

———, "New Western Plants," *Pittonia*, Vol. III, pp. 195–98, 1896–98. [Contains description of new species collected in the foothills and lower mountains of Colorado.]

———, "New Species of *Castilleia*," *Pittonia*, Vol. IV, pp. 1–2. [*Castilleia haydeni*, a common alpine species of southern Colorado described.]

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GREENE, EDWARD L., "New Western Species of *Rosa*," *Pittonia*, Vol. IV, pp. 10–14. [A number of specimens described were collected in Colorado.]

———, "New or Noteworthy Species," *Pittonia*, Vol. IV, pp. 35–45. [*Chrysothamnus formosus* collected among the hills southwest from Grand Junction, pp. 98–102. *Chaenactis pedicularia* collected in southern Colorado, pp. 146–58. A number of species from Colorado, pp. 318–20. Two species collected in Colorado by C. F. Baker.]

———, "New Species of *Antennaria*," *Pittonia*, Vol. IV, pp. 81–85. [Three species from Colorado.]

———, "West American *Asperifoliae*, IV," *Pittonia*, Vol. IV, pp. 86–97, 1899–1901. [This account includes descriptions of a number of Colorado species.]

———, "Some New or Critical *Ranunculi*," *Pittonia*, Vol. IV, pp. 142–46. [Three species from Colorado.]

———, "Some Rocky Mountain Asters," *Pittonia*, Vol. IV, pp. 212–16. [Many of these were collected in Colorado.]

———, "New Species of *Cerastium*," *Pittonia*, Vol. IV, pp. 297–304. [Including several species from Colorado.]

———, "Five New Species of *Rumex*," *Pittonia*, Vol. IV, pp. 304–6. [*R. polyrrhizus* collected by Mr. Osterhout from Lone Pine Creek, Larimer Co., Colo.]

———, "Studies in the Cruciferae, IV," *Pittonia*, Vol. IV, pp. 307–11. [One new species from Colorado.]

———, "A Fascicle of New Compositae," *Pittonia*, Vol. V, pp. 55–64. [Includes a number of specimens from Colorado.]

———, "New Species of *Eriogonum*," *Pittonia*, Vol. V, pp. 67–71. [Certain Colorado species.]

———, "New or Noteworthy Species," *Pittonia*, Vol. V, pp. 107–15. [Two species collected in Colorado.]

———, "New Species of *Polygonum*," *Pittonia*, Vol. V, pp. 197–203. [Two species from Colorado.]

———, "Certain Polygonaceous Genera," *Leaflets*, Vol. I, pp. 17–32, 1904. [A number of species from Colorado.]

———, "Some Western Buckthorns," *Leaflets*, Vol. I, pp. 63–65, 1904.

———, "Segregates of the Genus *Rhus*," *Leaflets*, Vol. I, pp. 115–28, 1905. [Describes a species from the mountain districts of Colorado.]

———, "Segregates of the Genus *Rhus*," *Leaflets*, Vol. I, pp. 129–44, 1905.

———, "New Plants from Southwestern Mountains," *Leaflets*, Vol. I, pp. 145–60, 1905. [Several species from Colorado.]

———, "The Genus *Ptelea* in Western and Southwestern U. S. and Mexico," *Contrib. from U. S. Nat. Herb.*, Vol. X, Part 2, pp. 49–78. [*Ptelea nitens*, n. sp., from canyon of the Arkansas above Canyon City.]

———, "A Study of *Rhus glabra*," *Proceedings of the Wash. Acad. of Sciences*, Vol. VIII, pp. 167–96, 1906.

GREENE, EDWARD L., AND BAKER, CARL F., "New or Noteworthy Plants from the Gunnison Water-Shed, Colorado," *Plantae Bakerianae*, Vol. III, Fasc. I, Washington, 1901.

GREENE, EDWARD L. (Baker, Carl F., Earle, F. S., *et. al.*), "Fungi to Gramineae,"

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*Plantae Bakerianae*, Vol. II, Fasc. I, Washington, D. C., 1901. [Plants collected in southwestern Colorado and New Mexico.]

GREENE, EDWARD L. (Tracy, S. M., and Earle, F. S.), "Fungi to Iridaceae," *Plantae Bakerianae*, Vol. I, Fasc. I, Washington, D. C., 1901. [Plants collected in southern Colorado.]

GRIFFIN, H. H., "The Cantaloupe Blight," *Bull. No. 64, Colo. Agricultural College Exper. Sta.*, pp. 12–17, 1901.

———, "Cantaloupe Blight in 1901," *Bull. No. 68, Colo. Agricultural College Exper. Sta.*, pp. 12–15, 1902. [A study of the fungus causing the disease.]

**Hall, Elihu, and Harbour, J. P.** Collected in 1862. Specimens studied and described by Asa Gray, which see.

**Harbour, J. P.** See Hall and Harbour.

**Hayden, F. V.** Collected in 1868.

HAYDEN, F. V., *Report of U. S. Geol. and Geog. Survey of the Territories.* [Twelve annual reports 1867–1878. Volumes III, IV and V contain articles on Colorado botany by Thomas C. Porter, Cyrus Thomas and Dr. C. C. Parry, which see. Final reports or monographs in five volumes. Bull., six volumes. Vols. II and VI contain articles on Colorado botany by Hooker, Gray and Brandegee, which see. *Miscellaneous Publication No. 4* is a "Synopsis of the Flora of Colorado," by Porter and Coulter. Seventeen volumes of unclassified publications.]

*Hayden Survey* (see above).

HEADDEN, WILLIAM P., "A Soil Study," *Bull. No. 46, Colo. Agricultural College Exper. Sta.*, pp. 1–64, 1898. [The object of this bulletin is to present the results of the author's study of the effect of alkali upon the composition of the sugar beet.]

———, "A Soil Study," *Bull. No. 65, Colo. Agricultural College Exper. Sta.*, pp. 1–55, 1901. [This gives a record of a number of analyses of some Colorado soils and a consideration of analytical results.]

———, "A Soil Study, the Ground Water," *Bull. No. 72, Colo. Agricultural College Exper. Sta.*, pp. 1–47, 1902.

———, "Colorado Hays and Fodders," *Bull. No. 93, Colo. Agricultural College Exper. Sta.*, pp. 1–44, 1904. [An account of alfalfa, timothy, native hay, corn fodder, sorghum and salt bush.]

**Henderson, Junius.** Made occasional collections in northern Colorado from 1895 to date. These in his private herbarium except a few in the University of Colorado herbarium. Address: Boulder, Colo.

**Holm, Theodor.** Collected in Colorado chiefly alpine plants in 1896 and 1899. The collections were made for comparison with the arctic flora with which Dr. Holm had become familiar in three expeditions with which he was connected (1882–83, 1884, 1886). Following are some of the places visited in Colorado: Clear Creek Canyon, Estes Park, Long's Peak, James Peak, Leadville, Twin Lakes, Mt. Massive, Gray's Peak, Torrey's Peak, Mt. Elbert, Mt. Kelso, Pike's Peak. The specimens collected are chiefly in Dr. Holm's private herbarium at Brookland, D. C., but some duplicates were sent to the Field Columbian Museum, Chicago, and others to the Royal Swedish Academy, Stockholm.

HOLM, THEODOR, "Studies in the Cyperaceae, XII, Segregates of *Carex filifolia* Nutt.," *Amer. Journ., Sci.*, Vol. IX, pp. 355–63, 1900.

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HOLM, THEODOR, "On Some Canadian Species of Gentiana," *Ottawa Nat.*, Vol. XV, 1900.

———, "Some New Anatomical Characters for Certain Gramineae," *Beih. Bot. Centralb.*, Vol. II, 1901.

———, "Studies in the Cyperaceae, XVI, Carices physocephalae and leucocephalae," *Amer. Journ. Sci.*, Vol. XIV, 1902.

———, "Studies in the Cyperaceae, XVII, Segregates of *C. tolmiei*," *Amer. Journ. Sci.*, Vol. XIV, pp. 417–25, 1902.

———, "Studies in the Cyperaceae, XIX, The Genus *Carex* in Colorado," *Amer. Journ. Sci.*, Vol. XVI, pp. 17–44, 1903.

———, "*Munroa squarrosa*," *Bot. Gaz.*, Vol. XXXIX, pp. 123–37, 1905.

———, "Claytonia, a Morphological and Anatomical Study," *Mem. Nat. Acad. Sci.*, Vol. X, 1905.

———, "Commelinaceae, Morphological and Anatomical Studies of the Vegetative Organs of Some North and Central American Species," *Mem. Nat. Acad. Sci.*, Vol. X, 1906.

———, "Botanical Excursions," *Ontario Nat. Sci. Bull.*, No. 3, 1907. [Makes comparison of floras of Novaja Zemlja, northwest coast of Greenland and James Peak, Colorado.]

———, "*Carex*" (Dr. Holm is joint author with P. A. Rydberg, in the account of Carex in the *Flora of Colorado*, see Rydberg).

———, "The Genus *Carex* in Northwest America," *Beih. Bot. Centralb.*, Vol. XXII, 1907.

———, "Method of Hibernation and Vegetative Reproduction in North American Species of *Stellaria*," *Amer. Journ. Sci.*, Vol. XXV, pp. 315–22, 1908.

———, "Studies in the Cyperaceae. XXVI. Remarks on the Structure and Affinities of Some of Dewey's Carices," *Amer. Jour. Sci.*, Vol. XXVI, pp. 478–93, 1908.

———, "The Alpine Gramineae of Colorado," *Bot. Gaz.*, Vol. XLVI, 1908.

**Holzinger, John M.** Made collections of mosses in May and June, 1896, visiting the foothills and canyons west of Ft. Collins, Pike's Peak, South Park, Palmer Lake and Leadville. Sets of fifty species were distributed as "Mosses of Colorado." Some new species were described from the collection by J. Cardot.

HOLZINGER, JOHN M., "Descriptions of New Plants from Texas and Colorado," *Contrib. from U. S. Nat. Herbarium*, Vol. I, pp. 286, 287, 1893.

**Hooker, Joseph.** Collected in Colorado in 1877 in San Luis Park and elsewhere with Asa Gray.

HOOKER, JOSEPH. Joint author with Gray, Asa, which see.

HOUSE, H. D., "Violaceae" in Rydberg's *Flora of Colorado*, pp. 232–34. (See Rydberg.)

JACK, JOHN G., "List of Trees and Shrubs Observed in the Pike's Peak, Plum Creek and South Platte Reserves," *20th Ann. Report U. S. Geol. Survey*, Part V. pp. 109–15 (Charles D. Walcott director), 1898–99.

———, "Pike's Peak, Plum Creek and South Platte Reserves," *20th Ann. Report U. S. Geol. Survey*, Part V, pp. 39–108, 1898–99. [A somewhat general account of the situation, general soil conditions, climate, rainfall and forest conditions with a description of the forest trees in the reserves. Thirty-six plates.]

**James, Edwin.** Botanist of Maj. Long's exploring expedition in 1820. Visited and made collections at the mouth of Platte Canyon and southward.

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JAMES, ENSIGN, SUDWORTH, *et. al.*, *Report on the Forest Conditions of the Rocky Mountains.* Issued as: *Dept. Agr. Forestry Div. Bull.*, No. 2, pp. 252, 1889, 2d ed.

JAMES, THOMAS P., "Musci," *U. S. Geol. Report (Wheeler Survey)*, Vol. VI, pp. 341–51. [Concise descriptions are given of the less known species.]

JARDINE, WILLIAM M., "Notes on Dry Farming," *Circ. No. 10, Bureau of Plant Industry*, June 12, 1908. [Describes a fruit farm 23 miles southeast of Denver.]

**Jones, Marcus E.** Made extensive collections in 1878 especially in the region of Pike's Peak and north to Boulder Canyon, west to Middle Park and Leadville. In later years extensive studies and collections were made in western and southern Colorado. Plants were sent to various European herbaria. All type specimens are now in Mr. Jones's private herbarium.

JONES, MARCUS E., "Trip to Pike's Peak," *Iowa College "News Letter,"* December, 1879. [An account of the botany of Pike's Peak.]

——— [an article on Colorado], *Iowa College "News Letter,"* January, 1879.

———, "Notes from Colorado," *Bot. Gazette*, December, 1879.

———, "*Simlax herbacea* var. *inodora* Jones," *Bot. Gazette*, December, 1879, p. 248.

———, "Reply to Meehan's Criticisms," *Bot. Gazette*, February, 1880.

———, "Climatologists' Meeting," *Salt Lake Tribune*, Sept. 7 and 9, 1890. [A report of the Denver meeting.]

———, "Canaigre Root," *Star-Times*, Grand Junction, Colo., December 6, 1894.

———, "Ferns of the West," *Utah Review*, Vol. I, No. 6, p. 179.

**Juday, Chancey.** Collected at Twin Lakes 1903 while acting Professor of Biology in the University of Colorado.

JUDAY, CHANCEY, "Studies on Some Lakes in the Rocky and Sierra Nevada Mountains," *Trans. Wis. Acad. of Sci., Arts and Letters*, Vol. XV, Pt. II, pp. 781–93, 1907. [Refers to aquatic vegetation and plankton. Chiefly concerned, however, with fish food.]

KING, CLARENCE. *A Report of the Geol. Exploration of the 40th parallel from Sierra Nevada to the Eastern Slope of the Rocky Mountains.* Final Report, Vol. V, Botany, by Sereno Watson, aided by Professor Daniel C. Eaton and others. Annual Reports from 1871 to 1878. [Contains no Colorado botany but listed here because frequently alluded to in work on Rocky Mountain plants.]

LAMSON-SCRIBNER F., "Criticism of Mr. Nash's *New or Noteworthy American Grasses*," *Bot. Gazette*, Vol. XXI, pp. 14–16, 1896.

———, "New North American Grasses," *Bot. Gazette*, Vol. XXI, pp. 133–39, 1896. [Two new species collected in Colorado by C. L. Shear and P. A. Rydberg.]

**Lees, J. Cardwell.** Made collections in extreme southwestern Colorado in the summer of 1892. These were listed by J. Cosmo Melvill, which see.

**Long's Expedition.** This exploring expedition to the Rocky Mountain country was commanded by Major Stephen H. Long, of the U. S. Army, in 1819. The purposes were to explore the Mississippi, above the mouth of the Missouri, then the Missouri and its tributaries and finally the country of the head waters of the Arkansas and Red rivers so as to learn something definite about the region on the American side of the newly established Spanish boundary line. The expedition acquired much valuable geographical and scientific knowledge of the western country. Dr. Edwin James was the historian and botanist of the expedition.

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**Longyear, B. O.** Instructor in Botany, Colorado Agricultural College. Address: Ft. Collins, Colo.

LONGYEAR, B. O., "The Evergreen Trees of Colorado," *Bull. 130, Colo. Agricultural College Exper. Sta.*, 1908. [A popular account intended for use of farmers.]

LOUD, F. H., "Meteorological Observations," *Colo. College Studies Gen. Series, No. 13, Sci. Series, Nos. 33–35*, Vol. XI, pp. 54–75, 1904–6. [A summary of meteorological observations from January to June, 1904.]

———, "Meteorological Observations," *Colo. College Studies Gen. Series, No. 13, Sci. Series, Nos. 33–35*, Vol. XI, pp. 77–84, 1902–6. [A determination of the number of hours' possible sunshine at Colorado Springs.]

———, "Meteorological Statistics," *Colo. College Pub. Sci. Series, Nos. 47–49, Gen. Series No. 23*, Vol. XII, pp. 275–306, 1906.

———, "A Comparison of Temperatures, 1906, between Colorado Springs and Lake Moraine," *Colo. College Pub. Gen. Series, No. 31*, Vol. XII, pp. 92–98, 1906.

MACMILLAN, CONWAY, "The Relative Altitudes of the Rocky and Appalachian Mountain Systems as Influencing the Distribution of Northern Plants," *Amer. Naturalist*, Vol. XXV, pp. 146–50, 1891.

**McFarland, J. I.** Collected plants for University of Colorado herbarium in Boulder County in 1881. His collections embraced a large number of specimens chiefly from the foothill region.

MARSH, C. DWIGHT, "Results of Loco Weed Investigations," *Bureau of Plant Industry Bull. 121*, Part III, 1908. [Experiments were carried on at Hugo, Colo. See Crawford, Albert C., on "Lab. Work on Loco Weed Investigation."]

**Meehan and Hooper.** Collected in 1871 and 1873. *Fide* Porter.

MELVILL, JAMES COSMO, "Notes on a Small Collection of Plants Collected in Southwest Colorado, by Mr. J. Cardwell Lees," *Mem. and Proc. Manchester Lit. and Phil. Soc.*, Series 4, Vol. VII, pp. 214–19, 1893. [List of 57 species with notes. The specimens were from the extreme southwest part of the state.]

**Mills, Enos A.** Has given many lectures on forests and forestry throughout the United States. Address: Estes Park, Colo.

MILLS, ENOS A., AND STONE, W. G. M. "The Forest and Exotic Trees of Colorado." Denver, 1905. [Pamphlet published by the Colo. State Forestry Asso.]

MORREN, E., "Excursion Botanique." A pamphlet of 64 pages detailing the results of the work of Marcus E. Jones in Colorado. Published at Liège, Belgium, 1878.

**Moseley, Frank Y.** Made collections in Boulder County for University of Colorado herbarium while assistant to the biological dept., in 1895–98. Address: Loveland, Colo.

**Nelson, Aven.** Collected in northern Colorado at various times since 1900. Has named nearly all specimens for University of Colorado herbarium collected by various persons. Has also studied collections made by private individuals who have visited the state. Address: University of Wyoming, Laramie, Wyo.

NELSON, AVEN, *Analytical Key to Some of the Common Flowering Plants of the Rocky Mountain Region.* [A 94-page book for use in schools: gives key and good descriptions to many of the most common plants. New York: D. Appleton & Co., 1902.]

———, "Some Rocky Mountain *Chrysothamni*," *Bot. Gazette*, Vol. XXVIII, pp. 369–77, 1899. [Describes *C. pumilus acuminatus* n. var. from La Veta, Colo. C. S. Crandall.]

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NELSON, AVEN, "The Western Species of *Aragallus*," *Erythaea*, Vol. VII, pp. 57–64, 1899.

———, "New Species of *Oreocarya* and its Allies," *Erythaea*, Vol. VII, pp. 65–70, 1899.

———, "Some Species of *Tetraneuris* and its Allies," *Bot. Gazette*, Vol. XXVIII, pp. 126–30, 1899. [Describes *T. mancosensis* n. sp. collected by Crandall at Mancos, Colo.]

———, "Contributions from the Rocky Mt. Herbarium II," *Bot. Gazette*, Vol. XXXI, pp. 394–409, 1901. [Gives an account of 300 plants sent by Professor Francis Ramaley from Colorado. Some collected by himself, some by F. Y. Moseley, some by Miss Jennie M. Archibald. Nine new species.]

———, "Contributions from the Rocky Mt. Herbarium III," *Bot. Gazette*, Vol. XXXIV, pp. 21–35, 1902. [*Lappula heterosperma homosperma* n. var. described from a collection by G. E. Osterhout, New Windsor, Colo.]

———, "Contributions from the Rocky Mt. Herbarium IV," *Bot. Gazette*, Vol. XXXIV, pp. 355–71, 1902. [Describes *Opulaster ramaleyi* n. sp. from Boulder, *Crataegus wheeleri* n. sp. from Sapinero, Colo., *Crataegus erronis* n. sp. from Cerro summit and from Boulder, Colo.]

———, "Contributions from the Rocky Mt. Herbarium V," *Bot. Gazette*, Vol. XXXVII, pp. 260–79, 1904. [Describes *Chrysopsis imbricata* n. sp. from Pike's Peak.]

———, "Contributions from the Rocky Mt. Herbarium VI," *Bot. Gazette*, Vol. XL, pp. 54–67, 1905. [Describes *Sphaerostigma tortum eastwoodae* n. var. from Grand Junction, Colo., also *Oreocarya pulvinata* n. sp.; *Chrysopsis cooperi* n. sp.; *Aster cordineri* n. sp.; *Crepis alpicola* (Rydb.); *Gilia exserta* n. sp.; *Amelanchier oreophila* n. sp.; and *Amelanchier elliptica* n. sp. from Colo.]

———, "Contributions from Rocky Mountain Herbarium VII," *Bot. Gazette*, Vol. XLII, pp. 48–54, 1906. [Describes *Prunus ignotus* n. sp. collected by C. S. Crandall at Ft. Collins, and *Philadelphius nitidus* n. sp. col. by H. N. Wheeler at Sapinero.]

———, "The Genus Hedysarum in the Rocky Mountains," *Proc. Biol. Soc. Wash.*, Vol. XV, pp. 183–86, 1902.

———, "*Psilostrophe*, a Neglected Genus of Southwestern Plants," *Proc. Biol. Soc. Wash.*, Vol. XVI, pp. 19–24, 1903.

———, "New Plants from Wyoming," *Bull. Torr. Bot. Club*, Vol. XXXI, pp. 239–47, 1904. [Names *Gentiana monantha* n. sp. from Mirror Lake, Colo.]

———, "Plantae Andrewseae," *Proc. Biol. Soc. Wash.*, Vol. XVII, pp. 173–80, 1904. [Describes a number of species collected by D. M. Andrews. *Asplenium andrewsii* n. sp. Boulder: *Nemexia herbacea melica* subsp. nov. Boulder; *Crataegus coloradensis* sp. nov. Boulder; *Crataegus cerronis* A. Nels., the fruit here given as black; *Eustoma andrewsii* n. sp. Boulder; *Pleurogyne fontana* n. sp. Boulder and S. Park; *Mimulus minor* n. sp. Boulder; *Erigeron macranthus mirus* n. var. Boulder; *Aster andrewsii* n. sp. Boulder.]

———, "Some Western Plants and Their Collectors," *Proc. Biol. Soc. Wash.*, Vol. XX, pp. 33–40, March 27, 1907. [Describes the work of various collectors and students, mentioning that done in Colorado by various people. Describes *Mertensia micrantha* n. sp. collected by Francis Ramaley and W. W. Robbins at Sugar Loaf, and *Douglasia johnstoni* n. sp. from near Long's Peak.]

———, "Is This Birch New?" *Bot. Gazette*, Vol. XLIII, pp. 279–81, 1907. [Describes *Betula andrewsii* n. sp. from north side of Green Mountain near Boulder, Colo.]

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NELSON, ELIAS, *Revision of Western North American Phloxes.* Laramie, Wyo., 1889. Pp. 36.

———, "A New Colorado *Antennaria*," *Bot. Gazette*, Vol. XXVII, pp. 212, 213, 1889.

**Newberry, John Strange.** Collected paleontological material and some recent plants in southern and western Colorado.

O'BRINE, D., "Soils and Alkali, Fertility, Irrigation, etc.," *Bull. No. 9, Colo. Agricultural College Exper. Sta.*, pp. 1–27, 1889. [This gives a record of a number of soil analyses from various parts of the state with comments on general fertility, etc.]

———, "Loco and Larkspur," *Bull. No. 25, Colo. Agricultural College Exper. Sta.*, pp. 1–26, 1893. [This is an illustrated account of loco and larkspur with reports of experiments made in investigating the so-called "loco" poisoning of cattle.]

——— (joint author with Cassidy, James, which see).

**Osterhout, George E.** Collections in various parts of Colorado since 1895. Specimens in his own private herbarium. Address: New Windsor, Colo.

OSTERHOUT, GEORGE E., "A New *Atriplex*," *Bull. Torr. Bot. Club*, Vol. XXV, No. 4, 1898. [*Atriplex fruticulosa*, growing in the saline soil of elevated table-lands of Colorado and Wyoming.]

———, "*Rumex densiflorus*" *Erythaea*, Vol. VI, February, 1898.

———, "New Plants from Colorado," *Bull. Torr. Bot. Club*, Vol. XXVI, May, 1899, pp. 256–57. [*Potentilla rupincola* and *Astragalus hypoglottis bracteatus* described.]

———, "New Plants from Colorado," *Bull. Torr. Bot. Club*, Vol. XXVII, pp. 506–8, Sept., 1900. [*Allium rubrum; Allium arenicola* (name changed to *Allium subulicola*), *Artemisia coloradensis; Artemisia speciformis; Artemisia cana viscidula* and *Agoseris montana.*]

———, "New Plants from Colorado," *Bull. Torr. Bot. Club*, Vol. XXVIII, 1901. [*Linum arkansanum; Mentzelia aurea* (name later changed to *Mentzelia speciosa*); *Artemisia silvicola* and *Agoseris agrestis.*]

———, "*Hesperaster nudus* (Pursh) Cockerell and its Allies," *Bull. Torr. Bot. Club*, Vol. XXIX, pp. 173, 174, 1902. [*Hesperaster strictus*, sp. nov.]

———, "New Plants from Colorado," *Bull. Torr. Bot. Club*, Vol. XXX, pp. 236, 237, April, 1903. [*Cryptanthe gracilis; Aulospermum planosum; Touterea multicaulis* and *Lepidium divergens* described.]

———, "Notes on Colorado Plants," *Bull. Torr. Bot. Club*, Vol. XXI, pp. 357, 358, 1904. [Describes new species *Arabis rugocarpa, Aulospermum angustum* and *Senecio fendleri lanatus;* and extends the range of a few old species.]

———, "New Plants from Colorado," *Bull. Torr. Bot. Club*, Vol. XXXII, pp. 611–13, 1905. [This account describes five new species: *Allionia sessilifolia; Aster fluvialis; Senecio lanatifolius; Carduus araneosus* and *Carduus spathulatus.*]

———, "Colorado Notes," *Muhlenbergia*, Vol. I, pp. 139–43, 1906. [Describes eight species chiefly from Sulphur Springs.]

———, "On the Mountain Top," *Plant World*, Vol. IX, pp. 132–36, 1906. [A popular account of a trip to the top of the range from Estes Park with list of some conspicuous alpine plants.]

———, "Flora of Colorado," *Muhlenbergia*, Vol. III, p. 65, 1907. [This is a review of Rydberg's *Flora* in which Osterhout mentions a number of species not there included: *Solidago speciosa* Nutt.; *Lacinaria spicata* (L.) Kuntze; *Pyrrocoma lanceolata* (Hook.)

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Greene; *Crepis gracilis* (Eat.) Rydb.; *Lobelia cardinalis* L., *Hydrophyllum virginicum* L., *Adenostegia ramosa* (Nutt.) Greene; *Ligusticum filicinum* Wats., *Gentiana calycosa* Griesb., *Thalesia uniflora* (L.) Britt., *Spiesia gracilis* A. Nels., *Astragalus lotiflorus*, Hook.; *Saxifraga caespitosa* L., *Ribes cynosbati* L., *Petrophyton caespitosum* (Nutt.) Rydb., *Hutchinsia procumbens* (L.) Desf., *Cardamine umbellata* Greene; *Thelypodium nuttallii* Wats., *Arabis rugocarpa* Osterhout.]

OSTERHOUT, GEORGE E., "Nuttall and Pursh and Some Early Spring Flowers of Colorado," *Plant World*, Vol. X, No. 4, April, 1907.

**Paddock, Wendell**, Professor of horticulture, Colorado Agricultural College. Address: Ft. Collins, Colo.

PADDOCK, WENDELL, "Plant Diseases of 1901," *Bull. No. 69, Colo. Agricultural College Exper. Sta.*, pp. 1–23, 1902.

———, "Large Potato Vines and No Potatoes," *Bull. 92, Colo. Agricultural College Exper. Sta.*, pp. 1–8, 1904. [This bulletin contains a condensed account of work with potato diseases.]

PADDOCK, W., AND ROLFS, F. M., "Potato Failures," *Bull. No. 64, Colo. Agricultural College Exper. Sta.*, pp. 21–23, 1901. [A record of experiments with potato fungus and a formula for treating diseased seed potatoes.]

PAMMEL, L. H., "Some Diseases of Rocky Mountain Plants," *Iowa Academy of Sciences* [reprint without volume number or date].

———, "Dr. Edwin James," *Annals of Iowa*, Vol. VIII, pp. 161–85 and 277–95. [A brief biographical sketch.]

———, "What the United States Government Is Doing for Forestry," *Proceedings of Iowa Park and Forestry Association*, pp. 57–70. Ames, Iowa, 1901. [Discusses some of the forest reserves of Colorado.]

PAMMEL, L. H., AND LAMSON, SCRIBNER F., "Some Notes on Grasses Collected in 1895 between Jefferson, Iowa, and Denver, Colo.," *Proc. Soc. Prom. Agri. Sci.*, Vol. XVII, pp. 94–104, 1896.

**Parry, C. C.** Collected in 1861 and various years as late as 1872 in different parts of Colorado.

PARRY, C. C., "Catalogue of Plants," *4th Ann. Report U. S. Geol. Survey (Hayden Survey)*, pp. 484–87. [A list of plants collected by C. Thomas in eastern Colorado and northeastern New Mexico, during the survey of 1869.]

PARSONS, GEO. H., "The Climate of Colorado and Its Effects upon Trees," *Dept. Agr. Forestry Div. Bull. No. 2*, 2d ed., pp. 221–36, 1889.

**Patterson, H. N.** Made collections on Gray's Peak and elsewhere through central Colorado, 1885 and as late as 1892.

PAYNE, J. E., "The Russian Thistle as Forage," *Bull. No. 64, Colo. Agricultural College Exper. Sta.*, pp. 15–17, 1901.

PECK, CHARLES H., "Fungi," in Porter and Coulter, *Synopsis of the Flora of Colorado*, pp. 163–64, 1874.

———, "New Colorado Fungi," *Bot. Gazette*, April, 1878.

**Penard, E.** This distinguished student of Protozoa spent some time in Boulder, Colo., in 1891 as the guest of the late Professor John Gardiner. See below.

PENARD, E., "An Enumeration of the Plants Collected by M. E. Penard in Colorado during the Summer of 1892" (should have been 1891), *Contributions from the Herbarium of Columbia College*, No. 75.

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PENARD, E. [a list of plants collected in Colorado 1891], *Bull. Herb. Boiss.*, Vol. III, No. 5, May, 1895.

**Pike's Expedition.** The expedition from St. Louis through what is now Missouri, Kansas and Colorado, to New Mexico, in charge of Lieutenant Zebulon Montgomery Pike, 1806, was the second expedition to the newly acquired Louisiana Territory. It was undertaken by the order of General James Wilkinson, Commander of the Army, the primary object being the safe delivery of the Osage Indians, then in St. Louis, to the town of the Grand Osage. A second object was the accomplishment of peace between various Indian tribes. A notebook was kept containing remarks upon the geographical structure, the natural history and population of the country through which the expedition passed. Some mineral and botanical specimens were collected and meteorological observations recorded. Pike's account of the expedition was published soon after his return to the eastern states. This has not been seen by the compiler of this bibliography.

**Porter, T. C.** Collected in 1872 and 1873.

PORTER, T. C., "Catalogue of Plants," *U. S. Geol. Survey of Wyoming and Contiguous Terr.* (*Hayden Survey*), Vol. IV, pp. 472–84. [This includes Dr. F. V. Hayden's collection from North Park, Colo., and another made by Mr. B. H. Smith in the region around the city of Denver 1869.]

———, "Calalogue of Plants," *5th Annual Report of U. S. Geol. Survey* (*Hayden Survey*), pp. 477–98. [Most of the plants comprised in this catalogue were collected during the expedition of Dr. F. V. Hayden to the head waters of the Yellowstone river 1871. A few were gathered by Dr. George Smith on Gray's Peak, Colorado.]

——— (asst. to J. T. Rothrock in writing *A Catalogue of Plants Collected in Nevada, Utah, Colorado, New Mexico and Arizona*), *U. S. Geog. Report of the Survey West of 100th Meridian* (*Wheeler Survey*), Vol. VI, pp. 53–352. [The following Colorado plants are described—Polemoniaceae, Hydrophyllaceae and Borraginaceae, pp. 197–204; Scrophularineae, pp. 209–17; Labiatae, pp. 221–25; Polygonaceae, pp. 228–32.]

PORTER, THOMAS C., AND COULTER, JOHN M., "Synopsis of the Flora of Colorado," *Miscellaneous Pub. U. S. Geol. Survey of the Terr.* (*Hayden Survey*), No. 4.

POWELL, J. W., *Report of the Explorations of the Colorado of the West and its Tributaries* five volumes. Final reports of U. S. Geog. and Geol. Survey of the Rocky Mountain region—eight volumes. Contributions to North American Ethnology. [These reports contain no Colorado botany but are here listed because likely to be referred to by students of Rocky Mountain plants.]

PURDY, CARL, "A Revision of the Genus *Calochortus*," *Proc. Calif. Acad. Sci.*, 3d series, Botany, Vol. II, No. 4, 1901. [P. 131, *Calochortus gunnisoni* redescribed from a specimen from Boulder, Colo., p. 149. *C. nuttallii;* in Nebraska and eastern Colo.]

**Ramaley, Francis.** Made collections of seed plants also ecological studies chiefly in northern Colorado from 1899 to date. Duplicate specimens sent to Professor Aven Nelson, University of Wyoming. Address: University of Colorado, Boulder, Colo.

RAMALEY, FRANCIS, "Seedlings of Certain Woody Plants," *Minnesota Botanical Studies*, pp. 69–86, 1899. [Describes germination and seedling of *Acer glabrum* from Colo.; also gives figure.]

———, "Comparative Anatomy of Hypocotyl and Epicotyl in Woody Plants," *Minnesota Botanical Studies*, pp. 87–136, 1899. [Anatomy of *Celtis occidentalis*, the only Colorado species.]

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RAMALEY, FRANCIS, "The Seed and Seedling of the Western Larkspur (*Delphinium occidentale* Wats.)," *Minnesota Botanical Studies*, pp. 417–20, August, 1900.

———, "Remarks on the Distribution of Plants in Colorado, East of the Divide," *Postelsia, Yearbook of the Minn. Seaside Station*, pp. 21–53, 1901.

———, "Mesa Vegetation," *Science*, N. S., Vol. XV, p. 455, 1902. [Abstract of a paper read at meeting of naturalists of central states.]

———, "The Cotyledons and Leaves of Certain Papilonaceae," *Univ. of Colo. Studies*, Vol. I, pp. 239–43, April, 1903.

———, "The Pubescence of Species of *Astragalus*," *Torreya*, Vol. III, pp. 38–40, 1903.

———, "Anatomy of Cotyledons," *Bot. Gazette*, Vol. XXXVII, pp. 388–89, 1904. [Studies on Colorado Ranunculaceae and Cruciferae.]

———, "Plants of the Florissant Region in Colorado," *Univ. of Colo. Studies*, Vol. III, pp. 177–85, June, 1906. [A semi-popular account with two half-tone plates.]

———, "Scientific Expedition to Northeastern Colorado, 8. Botany, Account of Collections Made," *Univ. of Colo. Studies*, Vol. IV, pp. 161–64, April, 1907. [Report on collections made by Gideon S. Dodds, with two half-tone plates.]

———, "Plant Zones in the Rocky Mountains of Colorado," *Science*, New Series, Vol. XXVI, pp. 642, 643, 1907. [Gives a statement of the conditions and limits of the plains zone, foothill zone, montane zone, sub-alpine zone and alpine zone of northern Colorado east of the great divide.]

———, "The Silva of Colorado, I, Trees of the Pine Family in Colorado," *Univ. of Colo. Studies*, Vol. IV, pp. 109–22, February, 1907. [Gives account of forest trees of value in Colorado with descriptions and keys of Pine family, also one drawing and one half-tone plate.]

———, "The Silva of Colorado, II, The Poplars, Aspens and Cottonwoods," *Univ. of Colo. Studies*, Vol. IV, pp. 187–97, April, 1907. [Descriptions, keys and six figures.]

———, "The Silva of Colorado, III, Woody Plants of Boulder County," *Univ. of Colo. Studies*, Vol. V, pp. 47–63, 1907. [Lists 112 species all based on herbarium specimens in University of Colorado herbarium or else on publications dealing with Colorado botany. Exact localities in the county given in nearly every case. Map and chart of distribution.]

———, "Botany of Northeastern Larimer County, Colorado," *Univ. of Colo. Studies*, Vol. V, pp. 119–31, and six plates, February, 1908. [Names and characterizes the different plant formations.]

———, "New Colorado Species of *Crataegus*" (with two figures), *Bot. Gazette*, Vol. XLVI, pp. 381–84, 1908.

———, "Studies of Mesa and Foothill Vegetation; 2. Climatology of the Mesas," *Univ. of Colo. Studies*, Vol. VI, pp. 19–31, 1908. [A comparison of the climate of the Mesas at Boulder with that of the plains.]

———, "The Botanical Opportunity in Colorado," *Univ. of Colo. Studies*, Vol. VI, pp. 5–10, 1908.

———, "Color Variations in Some Colorado Flowers," *Plant World*, Vol. XI, pp. 17, 18, 1908.

RAMALEY, FRANCIS, AND ROBBINS, W. W., "Plant Zones of the Mountain Lakes in Northern Colorado," *Science*, N. S., Vol. XXVII, p. 208, 1908. [This is an abstract of a paper presented at the Chicago meeting of A. A. A. S. January, 1908.]

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RAMALEY, FRANCIS, AND ROBBINS, W. W., "Rock Ridge Vegetation of Northern Colorado," *Science*, Vol. XXVII, pp. 208, 209, 1908. [Abstract of a paper read at the Chicago meeting of A. A. A. S. January 1908.]

———, "Ecological Notes from North-Central Colorado," *Univ. of Colo. Studies.*, Vol. V, pp. 111–17, 1908. [Describes vegetation at Red Mountain and the conglomerate plains and a gulch study on the North Box Elder.]

RANSOME, F. L., "Ecomomic Geology of the Silverton Quadrangle, Colorado," *Geol. Survey Bull. No. 182*, pp. 265. *House Documents*, Vol. XCVIII, 57th Congress, 1st session, 1901–1902. [An account of the climate and vegetation of the Silverton Quadrangle, pp. 13–29.]

**Redfield, J. H.** Collected in 1872. *Fide* Porter.

RENAULD, F., AND CARDOT, J., "New Mosses of North America," *Bot. Gazette*, Vol. XIX, pp. 237–40, 1894. [*Timmia austriaca* Hedw. var. *brevifolia; Pylaisia polyantha* Sch. var. *coloradensis* and *Brachythecium suberythrorrhizon* collected by J. M. Holzinger in Boulder, Colo.]

———, "New Mosses of North America," *Bot. Gazette*, Vol. XXII, pp. 48–52, 1896. [*Philontis venella* C. Meull. var. *coloradensis* found in Springdale, Boulder Co., Colo.]

RICHARDSON, A. D., "The Colorado Variety of the Douglas Fir," *Gard. Chron*, p. 244, 1903. [There are three geographical forms of this, *Pseudotsuga glauca, macrocarpa* and *taxifolia*. The Colorado variety is hardier than the Pacific form.]

**Robbins, Wilfred W.** Collected specimens for University of Colorado herbarium in 1906, 1907 and 1908 from various parts of northern Colorado. Ecological studies of the mesas and of mountain lakes. Address: University of Colorado, Boulder, Colo.

ROBBINS, W. W., "Tubular Ray Flowers in *Gaillardia aristata*," *Torreya*, Vol. VI, p. 190, 1906. [Material collected near Boulder.]

———, "Variation in Flower Heads of *Gaillardia aristata*," *Biometrika*, Vol. VI, pp. 106–8, March, 1908.

———, "Studies of Mesa and Foothill Vegetation; 4. Deciduous Trees and Shrubs of the Mesas," *Univ. of Colo. Studies*, Vol. VI, pp. 36–49, 1908. [Mesas south of Boulder. Colo. Maps, charts and photographs.]

——— (see also Ramaley).

ROBBINS, W. W., AND DODDS, GIDEON S., "Studies in Mesa and Foothill Vegetation; 3. Distribution of Conifers on the Mesas," *Univ. of Colo. Studies*, Vol. VI, pp. 31–36, 1908.

ROBINSON, B. L., "Three New Choripetalae from North America and Mexico," *Bot. Gazette*, Vol. XXVIII, pp. 134–36, 1899. [*Arabis crandallii* collected by Professor C. S. Crandall at Cimmarron, Montrose Co., Colo.]

ROLFS, F. M., "Potato Failures," *Bull. No. 70, Colo. Agricultural College Exper. Sta.*, pp. 1–19, 1902. [This is an account of a destructive disease of the potato, the nature of the fungus and its methods of attack, inoculation experiments, etc.]

———, "Potato Failures," *Bull. No. 91, Colo. Agricultural College Exper. Sta.*, pp. 1–33, 1904. [Gives the results of experiments and study of the potato fungus, plant injuries, spread of the disease and remedial measures.]

——— (joint author with Paddock W., which see).

ROSE, J. N. (joint author with Coulter, John M., which see).

ROTHROCK, J. T., "Notes on Colorado," *U. S. Geog. Survey West of the 100th Meridian*

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(*Wheeler Report*), Vol. VI, pp. 1–15. [An account of the flora of the open ground, the flora of the mountains, the timber and agricultural resources.]

ROTHROCK, J. T., "Notes on Economic Botany," *U. S. Geog. Survey West of the 100th Meridian* (*Wheeler Report*), Vol. VI, pp. 41–53.

———, "Catalogue of Plants," *U. S. Geog. Survey West of the 100th Meridian* (*Wheeler Report*), Vol. VI, pp. 53–352, 31 plates. [Plants collected in Nevada, Utah, Colorado, New Mexico and Arizona with descriptions of those not contained in Gray's *Manual of the Northern U. S.*, and Vol. V. *Geol. Explor. of the 40th Parallel.* Dr. Rothrock was assisted by the following botanists: Sereno Watson, George Engelmann, Professor Thos. C. Porter, M. S. Bebb, Wm. Boott, George Vasey, Professor D. C. Eaton, Thos. P. James and Professor Edward Tuckermann.]

**Rydberg, Per Axel.** Collected in August, 1895, with C. L. Shear chiefly grasses and forage plants. Most of the time was spent in the Clear Creek district. Other collections by Dr. Rydberg in Colorado were made in 1901, around Colorado Springs, Pueblo, Walsenberg, La Veta, Spanish Peaks, Huerfano Valley and Greenhorn Mountains. In 1890 and 1891 collections were made at Julesburg.

RYDBERG, P. A., "Notes on *Potentilla*, I," *Bull. Torr. Bot. Club*, Vol. XXII pp. 244–49, 1896. [Two species from Colorado.]

———, "Notes on *Potentilla*, II," *Bull. Torr. Bot. Club*, Vol. XXIII, pp. 259–65, 1896. [Two species from Colorado.]

———, "Notes on *Potentilla*, III," *Bull. Torr. Bot. Club*, Vol. XXIII, pp. 301–6, 1896. [Two Colorado species.]

———, "Notes on *Potentilla*, IV," *Bull. Torr. Bot. Club*, Vol. XXIII, pp. 394–99, 1896. [Five species from Colorado.]

———, "Notes on *Potentilla*, V," *Bull. Torr. Bot. Club*, Vol. XXIII, pp. 429–35, 1896. [Describes three species from Colorado.]

———, "Notes on *Potentilla*, VI," *Bull. Torr. Bot. Club*, Vol. XXIV, pp. 1–14, 1897. [Three species from Colorado.]

———, "*Antennaria dioica* and its North American Allies," *Bull. Torr. Bot. Club*, Vol. XXIV, pp. 299–304, 1897. [*Antennaria parvifolia* and *Antennaria microphylla* are found in Colorado.]

———, "Notes on Two Western Plants," *Bull. Torr. Bot. Club*, Vol. XXIV, pp. 90–92, 1897. [Account of *Lonicera glaucescens* and *Geum* (Sieversia) *turbinatum*. *Geum turbinatum* is found in the higher Rockies of Colorado.]

———, "A Monograph of the North American Potentilleae," *Memoirs Depart. Bot. of Columbia Univ.*, Vol. II, 1898. [Includes collections from Colorado, 112 plates, pp. 223.]

———, "Cespitose Willows of Arctic America and the Rocky Mountains," *Bull. N. Y. Bot. Garden*, Vol. I, pp. 257–78, 1896–1900, issued 1899.

———, "New Species from the Western United States," *Bull. Torr. Bot. Club*, Vol. XXVI, pp. 541–46, 1899. [*Allium neo-mexicanum* collected in south Colorado.]

———, "Composition of the Rocky Mountain Flora," *Science*, 1900.

———, "Studies on the Rocky Mountain Flora." [Many new species from Colorado.] I. *Bull. Torr. Bot. Club*, Vol. XXVII, pp. 169–89, 1900; II, *ibid.*, pp. 528–38; III, *ibid.*, pp. 614–36; IV, *ibid.*, Vol. XXVIII, pp. 20–38, 1901; V, *ibid.*, pp. 266–83; VI, *ibid.*, pp. 499–513; VII, *ibid.*, Vol. XXIX, pp. 145–60, 1902; VIII, *ibid*, pp.

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**Saunders, De Alton.** Collected in Colorado. *Fide* Rydberg *in litt.*

SHEAR, C. L. (joint author with P. A. Rydberg, which see).

SMALL, JOHN KUNKEL, "A Monograph of the North American Species of *Polygonum*," *Memoirs from Depart. of Bot. of Columbia College*, Vol. I, pp. 180, 84 plates. [Certain species from Colorado.]

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**Stone, W. G. M.**, president of Colo. State Forestry Assn. Has written many popular articles and delivered lectures on the subject of forestry. Address: Denver, Colo.

**Sturgis, Wm. C.**, a student of Myxomycetes. Has made numerous collections in different parts of the state. Address: Colorado College, Colorado Springs, Colo.

STURGIS, WM. C., "The Myxomycetes of Colorado," *Colo. College Pub. Gen. Series, No. 30, Sci. Series*, Vol. XII, No. 1, pp. 1–43.

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THÉRIOT, I. (joint author with Cardot, J., which see).

**Thomas, C.** Made collections in eastern Colorado in 1869. Plants catalogued by C. C. Parry.

THOMAS, CYRUS, "Agriculture of Colorado," *U. S. Geol. Survey of the Terr.* (*Hayden Ann.*), 1–3, pp. 229–51, 1867–69. [This is an account of the Denver district, giving the soil, climate, vegetation, irrigation, etc.]

**Torrey, John.** Made collections in central Colorado 1872.

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**Tracy, S. M.** Made collections in June and July, 1898, in vicinity of Durango, Mancos and also in the La Plata Mountains. Was with C. F. Baker and F. S. Earle.

TRACY, S. M. (author with Earle, F. S., and Greene, E. L., which see).

TRACY AND GALLOWAY, "Notes on Western Erysipheæ and Peronosporeæ," *Journ. of Mycology*, Vol. IV, pp. 33–36, 1888.

———, "New Western Uredineæ," (*Puccinea caulicola*), *Journ. of Mycology*, Vol. IV, p. 20, 1888.

**Trelease, William.** Made collections in Ute Pass and Mosquito Mountains near Leadville in 1886. Studied pollination of *Yucca glauca* in mountains above Manitou, 1890.

TRELEASE, WILLIAM, "The Yucceae," *Mo. Bot. Garden, 13th Ann. Report*, pp. 27–133, 99 plates, 1902.

TRIMBLE, R. E. (joint author with Carpenter, L. G., which see).

**Tweedy, Frank.** Collected in southwestern Colorado in 1896, in Boulder Co., 1902–3. Mr. Tweedy is a topographer for the United States Geological Survey and has made his collections incidentally.

**Underwood, Lucien M.** Made collections in Colorado in the summer of 1901.

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**Vasey, George.** Made collections in Colorado in 1868. "Rocky Mts. latitude 40°–41."

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**Wheeler, Herbert N.** Made collections at Sapinero in 1898 and in the Montezuma forest reserve in 1905–6. All of these now in the herbarium of the University of Colorado. Address: Forest Supervisor, Ft. Collins, Colo.

WHEELER, HERBERT N., List of plants collected at Sapinero, Gunnison County, during the summer of 1898. M. A. Thesis, University of Colorado, 1902. [Typewritten copy in University of Colorado library.]

**Wolf, John.** Collected at Grand Junction, in South park and elsewhere 1873.

WORSDELL, W. C. A criticism of "The Colorado Variety of Douglas Fir," written by A. D. Richardson, *Botanisches Centralblatt*, Vol. II, p. 501, 1903.

**Young, Robert T.** Made collections and ecological studies in Colorado during a number of years, ending 1905, while a resident of Boulder.

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VOLUME VI NUMBER 2

# THE UNIVERSITY OF COLORADO STUDIES

FRANCIS RAMALEY
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# CONTENTS

PAGE

1. THE CHARACTER OF THE FLAVIAN LITERATURE, 69–117 A. D. 81
FRED B. R. HELLEMS, PH.D.
Professor of Latin

2. THE COMPOSITION OF SOME COLORADO TUNGSTEN ORES . 93
JOHN B. EKELEY, PH.D.
Professor of Chemistry

3. GEOLOGY AND PETROGRAPHY OF THE SUGARLOAF DISTRICT, BOULDER COUNTY, COLORADO . . . . . 97
R. D. CRAWFORD, M.A.
Assistant Professor of Geology

4. STUDIES IN LAKE AND STREAMSIDE VEGETATION. I. RED-ROCK LAKE NEAR WARD, COLORADO . . . . . 133
FRANCIS RAMALEY, PH.D.
Professor of Biology
and
W. W. ROBBINS, B.A.
Instructor in Biology

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# THE CHARACTER OF THE FLAVIAN LITERATURE, 69–117 A. D.[1]

By Fred B. R. Hellems

Mais parmi cette multitude de médiocres écrits, mal devenu nécessaire dans une ville immense, opulente, et oisive, il se trouve de temps en temps d'excellents ouvrages, ou d'histoire, ou de réflexions, ou de cette littérature légère qui délasse toutes sortes d'esprits.—Voltaire, *Siècle de Louis Quatorze.*

The words of the illustrious Frenchman describing the literature of his own time, which corresponds in so many ways to the one under discussion, may be adopted with little modification as a general characterization of the writings of the Flavian period; but we should avoid a probable predisposition to lay undue stress on the innumerable mediocre productions and to slight the excellent. Coming naturally into comparison with the Augustan era, the Flavian period has inevitably suffered at the hands of the literary critic. The outburst of the former age came when the Tiber town, grown great, was flushed with the idea of victorious peace and established moderate government: it was the triumphal hymn of the eternal city. The productions of the latter came when peace had degenerated into idleness, and constitutional rule had sunk to a despotism which might be beneficent but had often been found most malignant; the literature was in its worst phases the gaiety song of the myopic hedonist, in its best, the protest of the seer. About the literature of a time of national exultation there is something of grace and polish, of joy and hope, of breadth and even of height, that appeals to the cultured reader or the literary critic. The writings of the Augustan age, appearing when the nation was jubilant, when letters were the immediate protégées of the ruling power and when the emperor aimed at a revival of the declining religion, breathe submission and orthodoxy; whereas the greater writings of our period breathe dejection, opposition and scepticism. But after all there may be about the literature of such a time of national depression something

[1] Strictly, of course, the Flavian dynasty ends in 96; but there is no interruption in the history of the literature with the death of Domitian, and any treatment of the period must include the reigns of Nerva and Trajan.



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of the wisdom and strength that in a people, as in an individual, can only develop from the trial as by fire, something of the spirit of greatness that appeals to the earnest student. Opposition frequently indicates the mind that distinguishes between merit and success, and the halting scepticism of today may generate the sublime onward-sweeping faith of tomorrow. Accordingly, while we find in the Flavian literature much imitation, for it follows a great period; much of the artificial, for life had been losing the naturalness of freedom; much adulation, for the writer was not independent; much of the trifling and ephemeral, for there was a widespread dilettantism; much of the low, for society was in many ways degraded; we find, on the other hand, much that is great and admirable, bearing the stamp of a true genius, which is not less valuable for being in many cases the genius of protest.

The relation of the Augustan literature to the Flavian influenced the latter in various ways. Previous to the appearance of the former the path of poetry had been difficult because it was so little trodden; after its appearance the path was difficult because it had been trodden so frequently. In this, perhaps, lies more of the explanation of the character of Flavian poetry than is generally supposed. After Vergil there could be no great epic poet until there came a new order of things. The true epic poem must sum up a period of history or thought; and there came no such new period until the era that inspired the Christian muse of Dante. After a band of poets like Horace, Catullus and the other myrtle-garlanded singers of that day, it must be a rare genius that could write successful lyric poetry before there was a new subjective basis. Accordingly, apart from other considerations, we should not confidently expect anything permanently valuable in these two great divisions of poetry; if there was to be anything abiding, it must be of a different kind. In prose, too, it is quite probable that the prevalence of the rounded and uniform style of Cicero developed a reaction which made it much easier for the other determining factors to mould the new form of expression with its distinctive features of *brevitas*, *varietas* and *poeticus color*.

The avenue, however, by which the Augustan era most directly influenced the Flavian was conscious or unconscious imitation. The

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epic poets would fain follow Vergil, and managed to keep in his tracks much as Ascanius may have toddled after Aeneas. The lyricists would strive to rival Tibullus and Catullus, and their effusions would frequently compare with the poems of their models as favorably as a crow with Lesbia's sparrow. The *Punica* of Silius Italicus and the *Thebaid* of Statius were manifestly inspired by Vergil, and both poems bear innumerable traces of the great classic model. Martial, whose striking originality in many ways would lead us to expect to find in him an exception, affords one of the best illustrations of the general tendency. Even the most casual reader of the epigrams will recognize many traces of the debt, and painstaking monographs have recorded the items according to the most approved dissertation system of bookkeeping. Martial is literally replete with imitations, adaptations, quotations and reminiscences from his predecessors in Latin poetry. Catullus was his great model and received the homage not only of outspoken praise, but also of imitation in countless details of expression and arrangement. Second only to Catullus is Ovid, as we should naturally expect; but Vergil, Horace, Tibullus and Propertius seem to have had less influence solely because we know that Ovid and Catullus had more. The prose writers were scarcely less susceptible to the same influences, as may be seen from Quintilian and Tacitus. The latter writer represents in a way the reaction from the rounded Augustan prose, and at the same time affords an excellent illustration of the influence at present under consideration. The *Annals*, the most characteristic work of the most characteristic author of Silver Latinity, exhibit the introduction into prose of many syntactical usages from the Augustan poets; the use of many single words in a sense hitherto limited to poetry; and finally the employment of expressions taken directly from the classic writers. The last feature is very prominent and many phrases in the *Annals* are parts of lines from the *Aeneid*. The directness and extent of the influence of the Augustan age on the Flavian is probably without a parallel in literary history.

But even more characteristic of our period than this indebtedness to its great predecessor, is a tendency to satire, heralded by Juvenal's *Difficile est satiram non scribere*. Of the six writers more commonly

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read, Statius, Quintilian, Pliny, Juvenal, Martial and Tacitus, the three last represent very markedly this general tendency. Statius escapes, probably because he comes dangerously near being a courtly pedant in comfortable circumstances, untroubled about the inner meaning of current events. Quintilian, from the nature of the subjects he is treating, is not affected by the satirical vein of the day. Pliny, the cultured gentleman, admiring polished dignity, loving praise and penning private letters gracefully for public circulation, does not exhibit the tendency in his own writings, although he is not so far removed from the general run of opinion that he cannot appreciate the salt of Martial's epigrams. Juvenal is an avowed satirist and on the thoroughness of his satire we need not enlarge; Martial in his epigrams is scarcely less fundamentally and effectively satirical than Juvenal; and Tacitus is hardly second even to the arch-satirist.

For this tendency Juvenal formally gives the reasons in his first satire, and the terrible list collected by him might be enlarged indefinitely from other sources. Generally the position taken by the satirist is about this: Socially and morally Rome has become unnatural and corrupt, politically she is presenting a farce which must soon have a tragic ending; let us try whether a little heroic treatment in the form of satire will benefit her in the evil hour.

The social condition of a people is always a difficult problem, and if it is hard to solve for one's own age, it is not easy to treat for another. However, the evidence for the period under discussion is exceptionally abundant and we should not be far astray in an estimate. On the whole, the social and moral life indicated by the literature is not attractive; but it is much better than it is represented in many writers. When one has floundered through the bog of a complete edition of Martial, feeling at every stage the pressure of the noxious air, one begins to think that life was only death. This pessimistic view is strengthened by the fact of the great epigrammatist's unquestioned popularity, and the frequent assertions[1] that he is read the world over, even by the chastest maidens of the outlying towns, where a little stricter morality might be hoped for than in the vicious capital. The culmination of one's amaze-

[1] V, 13, 16; VI, 61; VII, 52, 80, 88, 90; VIII, 72.

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ment is reached when one is confronted with the question of what society could have found pleasure in a still more abominable literature that seems to have been freely circulated among the reading public.[1] Juvenal's arraignment of the times is corroborated by the evidence of Martial, and we are compelled to believe that the less said about the moral and social corruption the less we shall have to decry and deplore. On the other hand, even if many more cases were typified by "Artemidorus amat"[2] than by "Calliodorus arat," there were many redeeming features. We have been too prone to base our judgments on the highly colored lines of Martial or Juvenal rather than the more subdued pages of men like Pliny, or on the quiet evidence of inscriptions. Tacitus puts forward the thought: "Nor were all things better in former generations; our age, too, has produced many examples of noble character and talent to be emulated by posterity;"[3] and in other connections he points out that the age is by no means barren of good qualities. Martial, despite his general popularity and his assurances of the purity of his heart, is called upon to answer charges of being unseemly in his freedom, so that there was evidently a certain element that had not sunk to the general level. Paetus and Arria, again, demonstrate the possibility of pure and undying conjugal affection even in the period of decline. These random cases serve to suggest the error of an unqualified condemnation of the moral life of the times; but they cannot altogether lighten the gloom that pervades the picture.

The political mask that disguised every citizen was a natural sequence of the vicissitudes of government through a hundred years. The reigns of the different monarchs had presented strange fluctuations, and the people had learned to rise and fall with the wave. How thoroughly and painfully this lesson had been grasped may be judged from Juvenal's sketch of the conduct of the populace after the fall of Sejanus.[4] Even more instructive is the estimate of the position by the great contemporary historian,[5] and probably we cannot do better than give a transcription thereof:

We read in history that Arulenus Rusticus and Herennius Senecio paid with their

[1] MART., XII, 43, 95.
[2] MART., IX, 21.
[3] *An.*, III, 55, fin.
[4] X, 81.
[5] TAC., *Agr.* 2 and 3.

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lives for their respective laudations of Paetus Thrasea and Priscus Helvidius; and that the rage of authority was not limited to the writers themselves but was even extended to their writings, and that the triumvirs were instructed to burn the memorials of these most illustrious men in the comitium and forum. They dreamed, I suppose, that by this fire the voice of the Roman people, the freedom of the senate, and the approving knowledge of the human race were being extinguished forever, since they had driven out the teachers of philosophy and forced every liberal pursuit into exile, lest anything honorable should anywhere confront them. Verily we have given a great example of long-suffering; just as the days of old saw the extreme of liberty, so our days have seen the extreme of slavery, having been deprived through the espionage of the informers of the very interchange of speech. Yea, memory itself we should have lost with our voice, if to forget had been in our power to the same extent as to be silent. Now at length life is returning. But, although in the very beginning of a most beneficent régime Nerva Caesar has brought together two things aforetime widely separated, the principate and freedom, although Nerva Trajan daily increases the happiness of the times, and public security has taken unto herself not only hope and prayers but the firm confidence of her prayers' fulfillment, yet in the nature of human weakness remedies are slower in operation than evils. Just as our bodies are slow in growth but rapid in destruction, so it is easier to tread out ability and zeal than to revive them. Nay, there actually comes upon a people a certain pleasure in mere inactivity: slothfulness is first hated and finally loved. Through a period of fifteen years, a great stretch of human life, many have fallen from natural accidents, and all our most energetic citizens from the cruelty of the prince; only a few of us are left, survivors, if we may use the expression, not only of others but even of ourselves, inasmuch as from the midspan of our life have been taken so many years, in which by a silent journey those of us who were in our prime have come to old age, and those of us who were old have arrived at life's very limits.

Turning to a consideration of the direct influence of the respective emperors we are able to trace with sufficient clearness the operation of their characters on the literature of their reigns. Since the work of Vespasian was so essentially preparatory, since the reign of Titus was practically inoperative from its brevity, and since the reigns of Nerva and Trajan are so closely identified, we may content ourselves with speaking of Domitian and Trajan.

Domitian, prior to his accession, unquestionably manifested a considerable interest in literature. This interest our authors generally consider entirely feigned; but it was probably more or less genuine. The fact of his having developed into a tyrant and stifled freedom of

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expression is no proof that in his leisured youth he had only pretended a zeal for letters and fine arts. Even during his reign, although in a mistaken way, he attempted to encourage literature merely from political shrewdness. But his actual influence was that of a strange disorder, which, while favoring the growth of much foliage, precluded the maturing of healthy fruit. The writer would find security for a harmless and insipid muse, and ready rewards for a prostituted muse; but for the muse that struggled to be chaste, or aspired to soar, there was either lack of encouragement or even active repression. Accordingly, the writings of his reign are for the most part placidly mediocre, or marred by the most cringing flattery. Servility and truckling could go no farther, and it was fortunate that Domitian was followed by a ruler great enough to be contented with temperate praise, and good enough to be praised without conscious blushing on the part of the eulogist.

The reigns of Nerva and Trajan were marked by a genuine revival in the spirit of literature. There were of course many things in common with the preceding reign, the same endless list of scribblers, and nearly the same general characteristics of style and language; but the tone was changed. Even upon the adulation of Martial the new rule exercised a beneficial influence. He loses some of the hypocrisy—not less repulsive for being so naïvely confessed—that had marked his previous work. In one of his epigrams,[1] worth nothing in itself as evidence, he gives a very good summary of the way the change was probably received by contemporaries.

In vain, nymphs of flattery, wretched and with worn lips, do you come to me. "Master" and "lord" (or even, "lord" and "god") will I not say. There is no longer place for you in this city of ours. Get you gone to the bonneted Parthians, and as base cringing suppliants kiss the feet of embroidered tyrants. We have no lord, but an emperor, a senator the most righteous of all, one by whose hands rustic Truth with uncared-for tresses has been brought back from the Stygian abode. Under this prince, O Rome, if thou art wise, look to it lest thou use the words erstwhile in vogue.

Pliny in his *Panegyric* harps almost with suspicious insistence on the new order of things as contrasted with the old, and his letters are almost equally laudatory. But Pliny, I take it, with his academic quietism,

[1] X, 72.

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despite his protests of the dangers he had undergone during the tyranny, could have written just as well under Domitian as under Trajan. The *Satires* of Juvenal, however, and the *Annals* of Tacitus mark the near approach to the ideal time "when a man might think what he wished and say what he thought."[1] There is a strength and virility about Juvenal, and a greatness and depth about Tacitus that imply freedom of expression, although we trace, at the same time, a previous development under repression and lack of freedom, such as characterize the reign of Domitian.

The poetical contests supported by the emperors apparently failed during our period to develop in the aspirants anything except servility and mediocrity. That competition and avowed rivalry might have a healthy influence on literature, when other circumstances co-operated, is shown most clearly by the abiding greatness of the Periclean drama. But the festival at Athens had been the occasion for the expression of all that was highest and best in the national life with its freedom and vigor. Here, if anywhere, the divine afflatus might be strengthened by human encouragement. The games at Rome in the time of Domitian, however, were under the immediate control of the tyrant himself, and there could be little voicing of the soul of a poet, when the prize must fall to polished and sounding verse lauding and magnifying the friend of Pallas and the Muses who presided, a present deity, at his own glorious festival.

Another feature making for flattery of the reigning power was the number, prominence and even predominance of writers from the provinces. To these the empire could but appear in another light than to the residents of the capital. The provinces had felt the benefits of imperial rule, and as yet very few of its evils. Their condition was, in truth, much better than it had been in the old days of the Republic when they had been plundered by the arbitrary greed of the successive officials much more oppressively than they were by the systematic exaction of a strong central government. To the provincials the emperor might, and often did, seem the embodiment of beneficent sovereignty, a being that they must respect and might even adore. The

[1] Rara temporum felicitate ubi sentire quae velis et quae sentias dicere licet. TAC., *Hist.*, I, 1.

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writers, then, who like Quintilian and Martial came from the outlying parts of the empire, cherishing no fond traditions of the old order of things, might find it much easier than their urban contemporaries to acquire the habit of adulation.

The education of the day, with its *narratio poetarum* and declamation, has a very perceptible connection with the character of the literature. Facility of production was acquired from the school even in early years, and it would not be hard to predict the sort of product. As a rule the poetry thus inspired would have just as much life and meaning as the prescribed Greek and Latin verse of later days. Given a subject, an educated young Roman would turn off any required number of lines with neatness and despatch. Thus Statius[1], whose pride is in his studied and barren epic, insists on the public's knowing that his *Silvae* are dashed off at about so many lines per hour as occasional productions. And, indeed, the composition of Latin and Greek verse was considered a proper and enjoyable recreation for a gentleman. It is scarcely remarkable that many of these scribblings, when the author with fond partiality ambitiously endeavored to give them vogue, either fell flat at their recitation, or, if published, came to serve as wrappers in the corner groceries.

The declamations could have an influence only for evil. To begin with, they fostered a spirit of conscious effort to gain approval, thereby developing a peculiar sort of vanity. They emphasized the sense of form and brought the subject-matter to be regarded merely as an excuse for the exhibition of stylistic skill. They developed an extravagance of imagination that helped to remove literature even farther than it was already straying from its proper field in human deed and thought; and this extravagance operating in another direction assisted in that cumbering of literature with what it was pleased to consider ornaments.

The fashion of recitation had one influence in common with declamations: it increased the striving after popular praise. The author at the reading of his poem or speech stretched his neck for every token of approval from his auditors, whose opinion was of more import than that of their modern representative, the book reviewer. This pre-

[1] *Silv.*, I, Praef.

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cluded any breaking away from the tastes of the day, and compelled the author, although he needed no compulsion, to follow without deviation the orthodox lines. So decisive, really, was the opinion of an audience that Pliny used his hearers as a sort of combined testing and corrective apparatus, noting carefully the effect of every expression. While there was such supreme regard for one's auditors, the average writer could be confidently trusted not to hazard anything by being so culpably original or individualistic as to rise above the dead level of mediocrity. Pliny,[1] as is his wont, sees the tendency but optimistically misinterprets it. In speaking of the favorable reception of his *Panegyric*, he says:

> And just as formerly the theatres taught the musicians to sing badly, so now I am led to hope for the possibility of these same theatres teaching the musicians to sing well. For all, to write for the purpose of pleasing, will write what they see does please.

Accordingly, we find developed a striving after effect that is more noteworthy for being so palpably conscious. What Afer says of the orator may with equal aptitude be applied to the writer:[2]

> I would have our orator like a wealthy and elegant head of a household, covered not merely by such a roof as will keep off wind and rain, but by one that will also delight the eye. The house itself should not merely be supplied with the furniture requisite for daily life, but should include in its plenishings gold and gems, so that to look at and handle these may often afford pleasure.

The effect of the beautiful roof and rich trappings was sought in many ways—rhetorical gilding, far-fetched and purely ornamental allusions, rare mouldings of vocabulary, epigrammatic points, and wire-drawn refinings in both prose and poetry; and poetical coloring in prose. A reference to the pages of Juvenal, Martial and Statius, or Tacitus will furnish abundant illustration.

Under such favoring circumstances grew the multitude of *médiocres écrits*. Of the spirit in which they were composed and, consequently, of their character we could have no better description than is to be found in an epigram addressed to Atticus,[3] a type of the *jeunesse dorée:*

> Prettily you declaim, my Atticus, and prettily plead in court, pretty the histories you write, pretty the songs you compose, prettily you philologize, and prettily astrologize. Prettily you sing, and prettily dance, prettily tune the lyre, and prettily ply the racquet. Although you do nothing well, you do everything prettily.

[1] *Ep.*, III, 18, 9; VII, 17, 13. [2] TAC., *Dial.*, 22. [3] MART., II, 7.

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And so it was with the majority of the composers of verse. Faultlessness of form it was quite possible to attain, but the very perfection of the exterior would only serve to emphasize the worthlessness of the contents. One could not wish a better subject for Goethe's

> Wir waschen und blank sind wir gans und gar,
> Aber auch ewig, unfruchtbar.

In conclusion it may be said that, despite all the weakness we have been criticizing, a literature including the works of Martial, Juvenal, and Tacitus can never be without strong claims to greatness. Martial, though he may be proved thoroughly contemptible on so many counts, stands unchallenged as the greatest epigrammatist in all literature. But it is Juvenal and Tacitus that bring to the age its glory. These two men saw with bitterness of spirit that the evil day was hard upon the country that ruled the world. In the blinding splendor of imperial sway over ever-broadening dominions their eyes did not fail to perceive evidences of the storms that were gathering to darken the scene and overwhelm theatre and actors together. It may be argued that it was by prejudice that their words were given to their pens, and that for the evils they decried they offered no remedy; but when men have frankly confronted the problem of their age, it is unsafe to assert that they have been influenced by the sinister aid of prejudice rather than by the sane help of genius. That they suggested no tangible remedy may be true; but it is possible there was no remedy to suggest other than the different social life they implicitly advocate throughout their works. At any rate they saw existing evils and cried out against them with no uncertain voice; they caught visions of impending ruin and can hardly be blamed for not proposing means to avoid what had become inevitable.

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# THE COMPOSITION OF SOME COLORADO TUNGSTEN ORES

By John B. Ekeley

For several years the mining of tungsten ores in Colorado has been carried on with profit, the richest deposits of this metal being found in Boulder County, principally in the Nederland region. It seemed, therefore, to be of interest to investigate the exact composition of these ores. Analyses were carefully made of samples from three different claims at Nederland. For the sake of comparison similar analyses were made of an ore from Ward, Colorado, of two from Silverton, Colorado, and of one from the Black Hills, South Dakota. These latter ores were not chosen for any particular reason, but were used simply because specimens happened to be at hand.

The method of analysis used was as follows. The ore was ground as finely as possible and decomposed with aqua regia. Complete decomposition takes place with difficulty in the case of high-grade ores, because the tungstic acid which first separates out forms a coating over the undecomposed particles, thus protecting them from further action by the acid. To avoid this a small quantity was taken for analysis, about 0.3 gram. The decomposition was carried out in a 600 c.c. beaker, the ore being spread out evenly on the bottom of the beaker after the addition of the acid. The beaker was heated upon a hot plate at a gentle heat without stirring the ore. In this manner, the ores, except in a few cases, were completely decomposed in about two hours. After dilution with water, the tungstic acid was washed with dilute acid, filtered off, and dissolved in dilute ammonia. The silica remaining in the beaker was again treated with aqua regia to be sure of complete decomposition of any ore particles remaining. The residue was washed, filtered, and treated with dilute ammonia as before. The silica was burned, weighed, and treated with hydrofluoric acid. The weighed residue was treated with concentrated hydrochloric acid, diluted with water, and any tungstic acid remaining was filtered off, washed, dis-



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solved in dilute ammonia and added to the major portion previously obtained, the whole being then evaporated to dryness, ignited, and weighed as $WO_3$. The iron filtrate was added to the filtrate from the aqua regia decompositions, and allowed to stand for twenty-four hours. Sometimes a slight precipitate of $WO_3$, which had passed through the filter, settled out. This was added to the tungstic acid solution obtained after treatment with ammonia. These steps are necessary in order to be sure of getting all the tungstic acid.

The iron and aluminum were separated by the sodium acetate method, the ignited precipitate fused with $KHSO_4$, dissolved and reduced, titrated with standard $KMnO_4$, and the alumina obtained by difference. The manganese was precipitated by ammonium sulphide, dissolved in acid, precipitated by ammonia and bromine water and estimated as $Mn_3O_4$. The calcium and magnesium were precipitated as oxalate and phosphate respectively. The ores were examined for moisture by Penfield's method, but in no case was an appreciable amount found.

As will be seen from the following tables, the Nederland ore is mainly tungstate of iron, the mineral ferberite. Most textbooks on mineralogy give a very brief description of this mineral, classifying it as a rarity. On account of its occurrence in such large quantity in Boulder County, it would hardly come under this class. None of the Nederland specimens showed even a trace of sulphur. Mr. Hugh F. Watts of Boulder, who has made over two thousand assays of these ores, tells me that it is not often that they show sulphur; in fact he has ceased making sulphur analyses on the ores, unless for special reasons. These specimens show only a fraction of a per cent. of manganese. The multitude of commercial analyses of these ores shows that rarely does the amount of manganese present run over one per cent.

The ore from Ward, Colorado, is a wolframite, carrying pyrite. The specimen showed the pyrite crystals very clearly. On this account the mineral has not been mined profitably.

The two ores from Silverton, Colorado, are hubnerite and a mixture of hubnerite and wolframite respectively. The hubnerite specimen was composed of light-brown bladed crystals, a single splinter being almost transparent. The small amount of iron was shown to be in

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the gangue between the crystals. The hubnerite-wolframite specimen showed a structure composed of black, bladed, acicular crystals, and, as shown by the analysis, was a mixture of almost pure hubnerite and woframite.

The Black Hills specimen was a wolframite, was black and of a coarsely granular structure. It contained some calcium carbonate.

Below is given a series of tables showing the analyses of the various specimens.

No. 1. Ferberite. Clyde Mine, Nederland, Colorado.

| | Per cent. |
|---|---|
| $WO_3$ | 61.15 |
| $SiO_2$ | 16.10 |
| FeO | 19.33 |
| CaO | .38 |
| MnO | .51 |
| $Al_2O_3$ | 2.49 |
| MgO | .39 |
| | 100.35 |

No. 2. Ferberite. Barker Ranch, Nederland, Colorado.

| | Per cent. |
|---|---|
| $WO_3$ | 65.88 |
| $SiO_2$ | 6.45 |
| FeO | 20.44 |
| $Fe_2O_3$ | 4.11 |
| CaO | .35 |
| MgO | .50 |
| MnO | .37 |
| $Al_2O_3$ | 2.19 |
| | 100.29 |

No. 3. Ferberite. Conger Mine, Nederland, Colorado.

| | Per cent. |
|---|---|
| $WO_3$ | 60.98 |
| $SiO_2$ | 15.94 |
| FeO | 19.13 |
| CaO | .44 |
| MnO | .08 |
| $Al_2O_3$ | 3.10 |
| MgO | .59 |
| | 100.26 |

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No. 4. Wolframite. Johnny Ward's Mine, Ward, Colorado.

| | Per cent. |
|---|---|
| $WO_3$ | 14.46 |
| $SiO_2$ | 78.30 |
| FeO | 4.06 |
| MnO | 1.45 |
| CaO | .32 |
| $FeS_2$ | 1.18 |
| | 99.77 |

No. 5. Hubnerite. Natalie Mine, Silverton, Colorado.

| | Per cent. |
|---|---|
| $WO_3$ | 70.21 |
| $SiO_2$ | 4.91 |
| FeO | 2.03 |
| CaO | .37 |
| MnO | 21.72 |
| $Al_2O_3$ | .56 |
| | 99.80 |

No. 6. Hubnerite-Wolframite. Sultan, Mt. Silverton, Colorado.

| | Per cent. |
|---|---|
| $WO_3$ | 74.09 |
| $SiO_2$ | .43 |
| FeO | 11.07 |
| MnO | 14.35 |
| | 99.94 |

No. 7. Wolframite. Near Lead, Black Hills, South Dakota.

| | Per cent. |
|---|---|
| $WO_3$ | 48.26 |
| $SiO_2$ | 26.21 |
| $CO_2$ | 2.67 |
| FeO | 10.00 |
| CaO | 3.40 |
| MnO | 7.56 |
| $Al_2O_3$ | 1.56 |
| | 99.66 |

*Chemical Laboratory, University of Colorado, Oct. 26, 1908.*

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# GEOLOGY AND PETROGRAPHY OF THE SUGARLOAF DISTRICT, BOULDER COUNTY, COLORADO[1]

By R. D. Crawford

## I. Topography

The Sugarloaf district is included in the region the topography of which has been well described by Dr. Fenneman as follows:

> The belt between the restricted mountain ridge on the west and the foothills on the east is 10 to 12 miles wide. Its generalized eastward slope is about 250 feet per mile, or from one-fourth to one-half that of the range proper. This strip is cut by narrow valleys to a depth of over 1,000 feet. The interstream areas are generally steep and narrow hills without flat tops, though some ridges continue for several miles with approximately level and unbroken crests. From any high point almost all the summits appear to be in the same plane. The range proper on the west and isolated lumps on the plateau rise with conspicuous abruptness, Sugarloaf Mountain, the top of which is 1,000 feet above the general level, being a prominent example. The topography at once suggests an imperfectly base-leveled surface that has been deeply cut by streams whose erosive power has been increased by recent elevation.[2]

More in detail, the area described in this paper is drained by Fourmile and Lefthand creeks with numerous short tributaries. The two main streams flow easterly through the district where each has cut a deep canyon with steep walls. The sides of Lefthand Canyon rise 1,300 feet within half a mile, and while the north side of Fourmile Canyon is somewhat less abrupt, on the south side within three-fourths of a mile Sugarloaf Mountain rises 1,800 feet above the bed of the stream. Between the valleys the surface possesses less relief; so gentle are some of the slopes that sufficient soil has accumulated to support a moderate growth of pine trees, and in several places cultivated land produces fair crops of grain and alfalfa.

Several of the prominent peaks and ridges have resulted from the high resistance of dike rocks. While pegmatite does not occupy the highest points as do the eruptives, it has been an important factor in

[1] I am indebted to Professor R. D. George for assistance in many microscopic determinations in the preparation of this paper.

[2] Fenneman, N. M., *Bulletin 265, U. S. G. S.*, p. 11.



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the preservation of some of the strongest ridges. But since the pegmatite dikes have been exposed to erosion far longer than the eruptive dikes, the latter often stand out more prominently than the former.

*Sugarloaf Mountain* is an excellent example of this. A strong dike of latite passes through the mountain the slopes of which are deeply buried beneath débris from the dike. At the top of the mountain the dike reaches a width of at least 50 feet. However, since the sides of the mountain are covered with slide-rock so deeply as to conceal the contact with the country rock, the exact width has not been determined, but an estimate of 100 feet would probably not be greatly in error. Toward the west the dike can be traced but a short distance, and on the northeast side of the peak it narrows to less than 20 feet within a distance of one mile, notwithstanding that at this latter point erosion has uncovered the dike 2,000 feet lower than its highest exposure. The extreme width on Sugarloaf Mountain and the existence here of smaller branches and shorter parallel dikes, mark this point as the center of vulcanism for this particular dike. It is not improbable that a fissure eruption once covered the surface with lava which protected from denudation, for a long period, the older rock as well as the dike itself.[1]

Although no lavaform rock can now be found in the region, it seems hardly reasonable to attribute to the dike properties of resistance sufficient to maintain its present elevation above the surrounding country. Within three-fourths of a mile northeastward the same dike is less resistant than the country rock, having weathered sufficiently to cause a depression in the surface. Even the dike must have extended, in comparatively recent times, several hundred feet higher than its present limit, since great quantities of dike rock hang on the slopes of the mountain and innumerable boulders have been carried long distances out into the plains by Boulder Creek.

[1] In the hope that I might find evidence for this hypothesis I requested Dr. Cross to allow me to examine the thin sections from pebbles found in the Denver formation, which he used in the preparation of his report in the "Denver Basin Monograph" (*Mon. 27, U. S. G. S.*) This request was kindly granted, but yielded only negative results. Among the slides examined there was apparently no effusive representative of the Sugarloaf rock. However, the pebbles from which these slides were made came from near Clear Creek rather than from near Boulder Creek. Even had I found the rock for which I was searching the evidence would be very remote.

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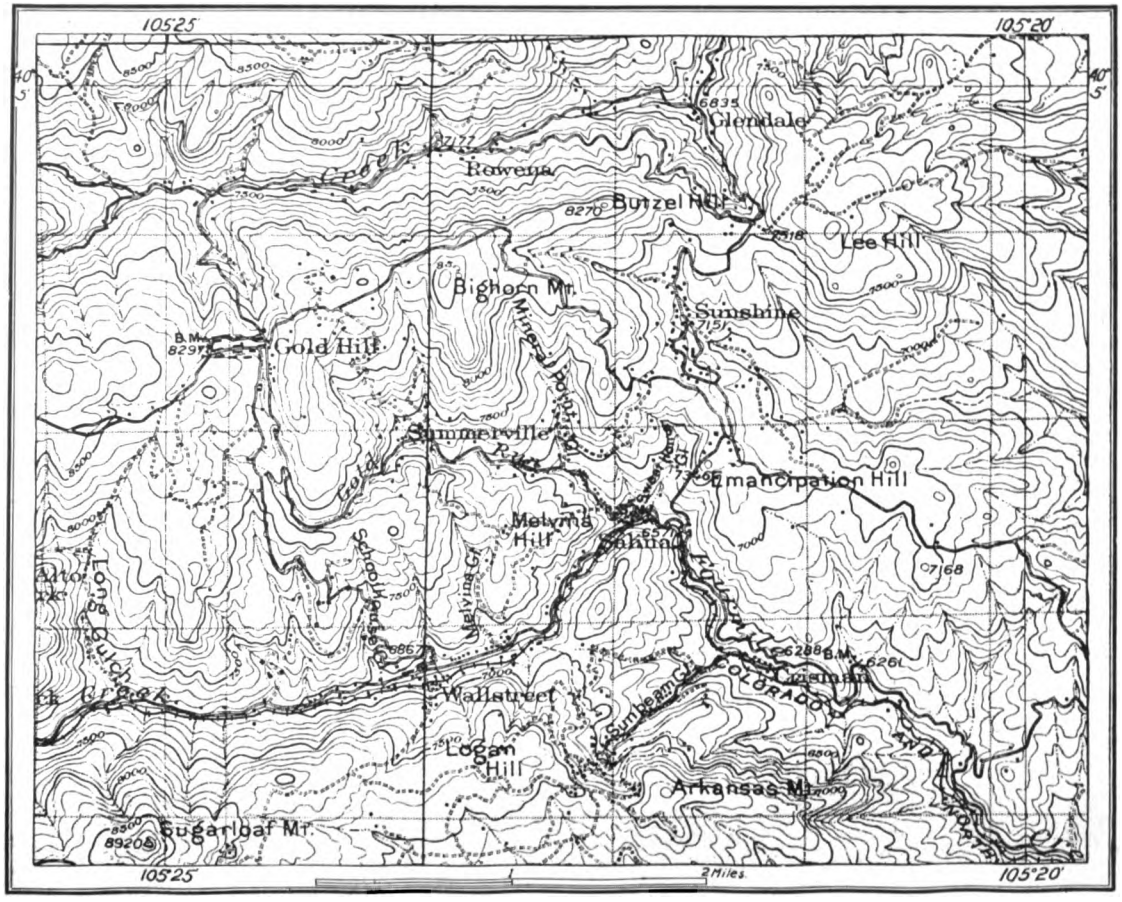
PLATE I




TOPOGRAPHIC MAP OF THE SUGARLOAF DISTRICT

This map is reproduced from the U. S. Geological Survey topographic sheet of the Boulder Quadrangle. The Survey furnished, as a base for geologic mapping, copies of the topographic map on a scale of approximately 2 inches to the mile.

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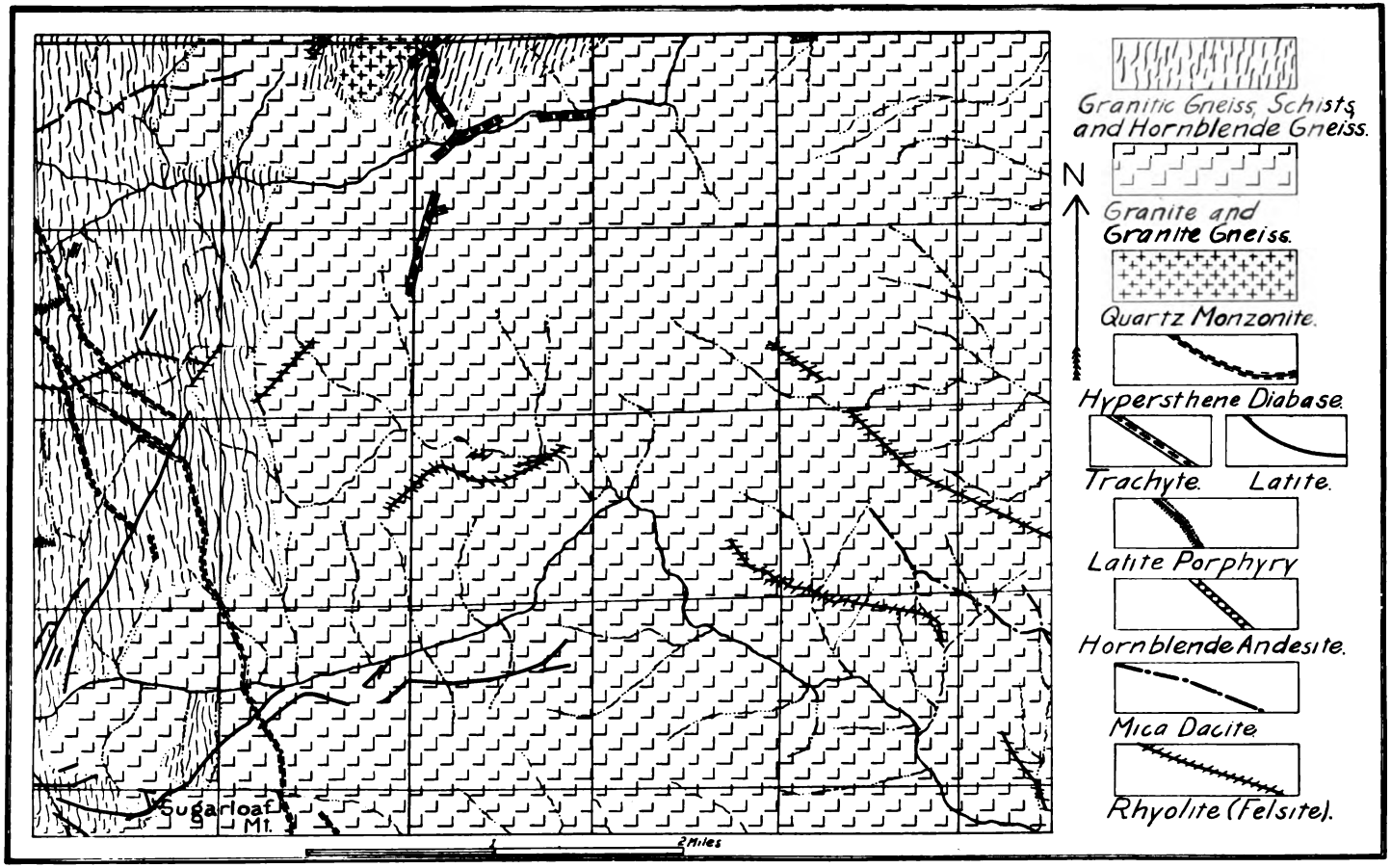
PLATE II




GEOLOGIC MAP OF THE SUGARLOAF DISTRICT

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## II. Rocks and Structural Relations

The rocks of the district include gneisses and schists, massive and gneissoid granites, pegmatite and aplite, quartz-monzonite, hypersthene-diabase, trachyte, latite, hornblende-andesite, mica-dacite and rhyolite.

### GNEISSES AND SCHISTS

Metamorphics occupy the western part of the area and extend many miles beyond the limits of the map. For considerable distances the contact with the granite may be well defined, but frequently weathering has produced so much mantle rock that the contact is concealed; in this case the boundary has been drawn where surface boulders indicate its probability. Nevertheless, it is very unlikely that the line so drawn is anywhere more than a few hundred feet out of place. Within the area mapped as gneiss and schist, near the contact with the granite there are numerous intrusions of the latter rock, sometimes several hundred square feet in extent. Also near the contact, in the granite area there are many large inclusions of the older rock. Where these conditions are found the exposures have been mapped as metamorphic or as granite according as the one or the other occurs in greater amount. Probably nowhere is this transition zone more than a quarter of a mile in width.

The gneisses and schists, which have been developed through regional metamorphism, are usually folded and often highly contorted. The foliation is roughly parallel to the contact with the granite, although locally, within a few hundred feet of this contact, the strike is approximately at right angles. The dip is everywhere high, rarely less than 60° from the horizontal, and commonly away from the granite.

#### Granitic Gneiss

Granitic gneiss occurs over a far wider area in the district than any other metamorphic rock. Quartz, feldspar and mica are the essential megascopic constituents, with garnet and muscovite as occasional accessories. Sometimes pyrite is seen in small grains, usually scattered over the surface in the joint-planes. Almost every degree of foliation can be found, from that of a coarse gneissoid granite to that of a finely laminated mica schist. Lenticular masses of pegmatite, from a few

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inches to many feet in longest diameter, are not infrequently present. Sometimes the lenses overlap, that is, a thin band of gneiss will cut across a lens dividing it at an acute angle with the long axis.

When examined with the microscope quartz proves to be the most abundant constituent, sometimes almost to the exclusion of other colorless minerals, when the rock approaches a quartz-schist in composition. Undulatory extinction is common, and liquid inclusions, each with a gas bubble, are numerous. The inclusions are commonly in rows parallel to the cleavage of the rock. These rows, as well as lines of fracture, can often be traced across the slide, passing from one quartz grain to another without interruption or change in direction. The feldspars are microcline, orthoclase, and plagioclase, the last with the extinction angle of albite. The total amount of feldspars is less than that of quartz. Biotite is universally present and generally with parallel orientation. Muscovite, quartz, magnetite and hematite are common alteration products. In a few cases muscovite is present in flakes 4 or 5 mm. in diameter in rock which is apparently very fresh. When this is examined in thin section the muscovite appears to be intergrown with the biotite, showing no evidence of having been derived from it. Sillimanite occurs in less amount, usually in small bundles of fibers surrounded by biotite. Epidote is a common secondary mineral, usually on the borders of mica flakes, less often associated with the feldspar. The garnet is colorless in thin section, and greatly fractured. In the specimens examined it shows no double refraction. Zircon and apatite are enclosed in small amount in the quartz and feldspars. The apatite crystals are often needle-like, with the long axes parallel to the rock cleavage. These long crystals are usually jointed or broken.

### Muscovite-Schist

The presence of muscovite in the granitic gneiss has been mentioned. In the gneiss there are also bands of finely laminated muscovite-schist from a fraction of an inch to many feet in width. One of the largest exposures is in the extreme northwest corner of the area mapped. The schist is really only a phase of the granitic gneiss, but because of its individual character it deserves some notice.

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The unaided eye readily recognizes in addition to the muscovite, nearly an equal amount of quartz and flakes of biotite. The microscope shows the muscovite to be intergrown with the biotite in some cases, and entirely distinct from it in others. That it may be in part an alteration product from the biotite is indicated by the presence of secondary magnetite. Quartz occurs not only in grains between the mica flakes, but is also enclosed in the muscovite, producing distinct micropoikilitic texture. The quartz contains liquid inclusions arranged in rows parallel to the foliation, and apatite needles extending in the same direction. Minute zircon crystals are enclosed in both muscovite and quartz.

### Sillimanite-Schist

The best exposures of sillimanite-schist are in the metamorphic area northeast of Sugarloaf Mountain at short intervals along the line of the latite dike. The rock is dark colored and closely packed with small bundles of sillimanite crystals which range from short, minute fibers to prismatic crystals 15 mm. long and less than 1 mm. thick. The sillimanite is light in color and becomes bleached on weathering, thus accentuating the contrast with the remainder of the rock. The interspaces are filled with biotite, and small flakes of muscovite are common in the most weathered specimens. The schist is in bands alternating with layers of an aggregate of quartz and feldspar. Lenticular masses of pegmatite are also present, but of smaller dimensions than those in the granitic gneiss.

Under the microscope the sillimanite crystals are usually seen to be broken with the fractures healed by a secondary colorless mineral. A few minute zircons are enclosed in the sillimanite. The biotite has formed later and forms a matrix for the sillimanite. Often a single crystal of biotite will enclose a number of fibers of the earlier formed mineral in poikilitic manner. In one slide examined the biotite encloses slender microlites intersecting at an angle of 60°. They thus have the habit of rutile but are colorless and resemble the sillimanite. They are too small, however, for certain identification. A small amount of orthoclase is present, involving the sillimanite crystals in the same manner as does the biotite.

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### Hornblende-Gneiss

In various parts of the metamorphic area there are dike-like masses of a dark, sometimes black, heavy gneiss whose principal mineral is hornblende. Small shiny flakes of biotite, white feldspar, and rarely quartz can also be seen with the unaided eye. Occasionally narrow veins of pegmatite are present. The rock is from medium- to coarse-grained, extremely tough and breaks with difficulty under the hammer. Gneissoid structure is strikingly noticeable in the field, but not always so apparent in the hand specimen.

Whatever may have been the original rock from which the schists and granitic gneiss were developed, the hornblende-gneiss is, almost without doubt, the result of metamorphism of basic igneous rocks. Since they do not appear to have been subjected to the intense dynamo-metamorphism, or dynamo-chemical metamorphism, which has produced the granitic gneiss, it is possible that basic dikes were intruded into the granitic gneiss after the latter had suffered metamorphism for a considerable period. These dikes would thus be in a position to feel the effects of subsequent strain and shearing possibly not more intense than that which developed the granite-gneiss described below. The presence of pegmatite veins, while far from conclusive evidence, is at least suggestive of the intrusion of the basic rocks subsequent to the most important period of metamorphism.

Microscopically the rock shows a considerable range in the relative proportions of the subordinate minerals. These are biotite, plagioclase, microcline, orthoclase and quartz, with pyrite, black iron ore, titanite and zircon as accessories. The hornblende is green and strongly pleochroic, except in a few cases where it has altered to a colorless variety with high double refraction. Twins are quite common. Terminal crystal boundaries are seldom present, but the characteristic outline is often seen in cross-sections. Frequently the hornblende encloses magnetite, quartz and feldspar in poikilitic manner. The last two minerals sometimes penetrate, or apparently gouge into the sides of the hornblende crystals. Most of the hornblendes lie with their long axes in parallel planes.

Biotite in small amount is universally present, and sometimes inter-

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grown with the hornblende. In importance, plagioclase is next to hornblende, but varies widely in amount in different dikes. Much, if not all, is labradorite. It is commonly twinned after both albite and pericline laws. In some sections the labradorite encloses minute brown crystals apparently prismatic in habit. Microcline and orthoclase appear only occasionally. Quartz is present in fairly large grains in some specimens; in others it is in minute patches probably as an alteration product. In the larger masses it exhibits phenomena identical with those noted in the quartz of the granitic gneiss. Black iron ore is present in all the slides examined. Granular titanite is more rare, and occurs only in sections that contain a small amount of iron ore.

It is possible, if not probable, that the original rock was a gabbro or diabase, and in some exposures, in so far as the mineral composition and structure are concerned, the present rock might well be called a hornblende-gabbro-gneiss.

## GRANITES

Within the area under consideration is a small part of the granite batholith which extends many miles north and south. On the west it is in contact with the metamorphic rocks; on the east, about a mile beyond the boundary of the map, it passes under the upturned sedimentaries of Carboniferous and later periods. In this district the granites fall into two classes: (1), hornblende-bearing biotite-granite often porphyritic, which has undergone a considerable degree of metamorphism and through which run numerous pegmatite and aplite dikes; (2), a porphyritic variety of biotite-granite intruded into the older granite and which, because of its occurrence near the village of Glendale, is here called Glendale Granite.

### Biotite-Granite (Hornblende-bearing)

No attempt has been made to map the even-grained and the porphyritic facies separately since they grade into each other and have crystallized from the same magma with essentially the same mineral composition. Although the granite is often massive, gneissoid structure is present over wider areas and is often pronounced. This applies equally to the even-grained and the porphyritic varieties. The color ranges from a light gray to bluish and dark gray, depending on the

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ratio of ferromagnesian minerals to light-colored constituents. Pink and purplish colors sometimes present in the feldspars may modify the tones, but probably nowhere is the unaltered rock red. Weathered surfaces may sometimes be stained red or brown by ferric oxide, and locally weathering may extend to considerable depths. The first product of disintegration is a mixture of angular fragments of feldspar and quartz, gray to brownish-gray in color. Further decay, where the rock is protected from rapid erosion, results in a clay-like product brownish-yellow in color.

The megascopic minerals are feldspar, quartz, biotite and hornblende named in the order of importance. The feldspar is commonly white, but pink and purplish crystals are not rare. Individuals vary in size from grains which can barely be distinguished by the aid of a lens to irregular masses 2 cm. in diameter, and in the porphyritic variety, to crystals 5 cm. long. Quartz, somewhat less abundant than feldspar, occurs in grains usually less than 1 cm. in diameter. The ferromagnesian minerals are variable in quantity; in places they almost disappear, yet frequently are so plentiful as to give the rock a very dark color. Biotite is nearly always present and generally to the exclusion of hornblende, though locally the granite contains biotite and hornblende in nearly equal amount, and sometimes grades into a granodiorite with a large proportion of hornblende and little or no biotite.

Under the microscope microcline is seen to be the most important feldspar, sometimes fully equal to the combined amounts of all other constituents. It invariably shows polysynthetic twinning after the albite and the pericline laws. Crystal outline is completely lacking, the mineral having crystallized contemporaneously with quartz and orthoclase. Micropegmatitic intergrowths of quartz and microcline are rarely present; sometimes the two minerals are intergrown in such a manner that tongues of one mineral penetrate the other. The microcline is usually quite fresh, though sometimes it is turbid from kaolinization and less often shows alteration to sericite. The phenocrysts of the porphyritic facies are, in part at least, microcline.

Orthoclase is generally much less abundant than microcline; while it may rarely equal or even exceed microcline in amount it is almost

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entirely absent from several slides examined. It is occasionally intergrown with quartz in a manner similar to that of microcline. Frequently it has two good cleavages. Sometimes it shows cloudy extinction indicating the strain to which the rock has been subjected. Twinning is after the Carlsbad law, and comparatively rare. Alteration products are identical with those of microcline.

Plagioclase is very generally distributed in small amount, but in specimens in which hornblende is plentiful it is in excess of orthoclase. The maximum extinction angle of 20° in sections normal to the albite lamellae would indicate that it is in large part albite or albite-oligoclase, though more calcic varieties may be present in the granodiorite phase. Pericline twinning frequently accompanies albite twinning, and Carlsbad twins are occasionally present. Although the plagioclase is frequently very fresh, calcite, kaolin, sericite and less often, epidote occur in small quantity as alteration products.

Quartz occurs in all the slides examined, though sometimes in small quantity. The hornblendic granite carries very little quartz. Undulatory extinction is very common, especially in those sections having much microcline, and the quartz is commonly fractured. Fluid inclusions are abundant, usually in bands intersecting at high angles. Often one strong band will be crossed by several parallel bands.

Biotite is almost a universal constituent, and usually in plentiful quantities. It is generally green to brown and strongly pleochroic. Sometimes the lamellae are flexed as the result of strain. Weathering commonly produces muscovite with the separation of magnetite and limonite. Often green chlorite and magnetite result from the alteration of biotite, and epidote is a frequent secondary mineral. The green hornblende, which ranges from an accessory to the dominant ferromagnesian mineral over small areas, is strongly pleochroic. Although often fresh, it sometimes shows alteration to epidote or to magnetite and quartz. That the hornblende and biotite crystallized simultaneously is indicated by idiomorphism of the hornblende toward biotite, but in the same field, small inclusions of the latter mineral in the former.

Muscovite may be primary where it appears to be intergrown with biotite. More often it has resulted from the leaching of biotite, and

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in the form of sericite from the alteration of feldspar. Apatite included in the feldspars, quartz, and biotite, is very common. Zircon in small stout crystals included in quartz and all the feldspars is a constant accessory. Hematite occurs associated with biotite from which it has been derived, and is sometimes seen throughout a thin section in the form of red powder. Magnetite occurs sparingly enclosed in hornblende, but is a common secondary mineral.

**Basic Secretions.**—Throughout the granite are numerous masses of darker rock usually less than a foot in diameter, but sometimes three feet or more across. They are commonly elliptical in outline, though irregular and sharply angular forms are not rare. Common hornblende makes up nearly one-half the rock. Plagioclase, biotite, and orthoclase are the other essentials named in the order of importance. Small zircon crystals, included in the feldspars, are numerous. The maximum extinction angle noted in sections of plagioclase normal to the twinned lamellae was 25°, somewhat higher than that of the plagioclase in the biotite-granite.

There is not much question that these "knots" are segregations of the earlier-formed minerals rather than xenoliths. Although they are often apparently sharply differentiated from the enclosing granite, in a few instances they can be traced, by the gradual failure of hornblende and the appearance and increase of quartz, into the normal granite. This may be seen at the side of the railroad a short distance west of Salina. It is probable that a few small masses, schistose in structure and badly decomposed, are the remnants of rock older than the granite.

**Fine-grained Biotite-Granite.**—A fine-grained gneissoid granite in dike-like masses occurs at various points throughout the granite area, but is best developed at Salina. A large body of this rock is exposed west of the depot, and the same dike crosses the creek a few yards below. Other exposures can be seen in the village on the north side of Gold Run, and a similar rock occurs at Wall Street. Constituent minerals are microcline in large amount, some orthoclase, quartz with undulatory extinction, and much biotite with basal sections in parallel planes. The feldspars and quartz carry numerous zircon inclusions.

The relation of this rock to the enclosing granite is not quite clear.

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In places it appears to form a contact with the coarser granite on one or both sides of the dike as well defined as that of any of the porphyry dikes, and even contains what appear to be inclusions of the coarser granite. But since the Salina dike is cut by pegmatite, and since in other parts of the district the fine-grained variety can be traced into the coarse-grained granite, it is inferred that it is a differential phase of the same magma.

**Metamorphism.**—Over considerable areas gneissoid structure is so marked and the results of dynamo-metamorphism so evident as to make the term granite-gneiss the most suitable name for the rock. The fracturing and undulatory extinction of quartz, the cloudy extinction of orthoclase and the bending of biotite flakes are results of strain; a less conclusive evidence is the fact that the potash feldspar has so generally assumed the triclinic form. Just east of Summerville is an exposure of the porphyritic granite which has been sheared and squeezed so that the phenocrysts have been drawn out into lens-like forms and the groundmass has become distinctly banded. In a few instances the gneissoid structure may be a fluxional arrangement as indicated occasionally by the parallelism of the feldspar phenocrysts in the porphyritic facies. But in addition to the granite-gneiss mentioned there are many bands from a few inches to scores of feet in width in which the parallelism of the dark minerals approaches perfect schistosity, which cannot be explained without assuming severe compression as an important cause. A finely laminated chlorite schist occurs in a band about three feet wide, south of the railroad a short distance west of Wall Street. The compression that produced the schistose structure was probably the result of shearing movement. Other evidences of movement are present, as in the many faults, usually of small throw, best seen in connection with pegmatite and aplite dikes. Slickensided granite indicates that movement of considerable importance occurred along a north-south line passing through Orodell on Fourmile Creek just east of the area mapped. The bands of schistose rock mentioned above commonly trend north and south

Metamorphosed granite in Sunbeam Gulch, on Logan Hill and west of Sunshine, occurring in narrow streaks, differs from all the other granite in the district in the high content of epidote and magnetite. It

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is almost always yellowish-green and contains magnetite varying from grains just identifiable with the unaided eye to perfect octahedrons 1.5 cm. in diameter. Under the microscope the original mineral composition cannot be exactly determined; quartz, microcline, epidote, kaolin, magnetite and small crystals of zircon are the present minerals. A specimen found near Sunshine contains many grains of magnetite, but looks and feels like sandstone. In thin section quartz, orthoclase, and plagioclase are seen in small grains, with a little hornblende, numerous zircons, and grains of epidote.

### Pegmatite and Aplite

Dikes of these rocks, from a few inches to many yards in width, cut the granite in all directions, and two persistent pegmatite dikes cross the area trending about N. 25° W. One passes near Sunshine where it is well developed; the other, the Hoosier Dike, crosses Fourmile Canyon between Salina and Wall Street and is very prominent at Summerville and east of Gold Hill. As seen on the surface, quartz and potash feldspar usually make up most of the rock, the quartz often in masses of large dimensions, sometimes 35 feet across. No microscopic determination of the feldspar was made except in the case of graphic granite which is often locally developed. In this case the feldspar was microcline in pegmatitic intergrowth with quartz. Other minerals occurring in amounts variable from place to place are muscovite, biotite and magnetite; and in one instance in Sunbeam Gulch, hornblende in aggregates two inches in diameter is found with the quartz and feldspar. Muscovite and biotite are not often seen in the coarsest pegmatite, possibly having been weathered out; but in the finer-textured variety crystals of either may be found up to two inches in diameter.

The aplite is composed of quartz, microcline and orthoclase, with small amounts of biotite, muscovite and epidote, the last two probably secondary. Minute crystals of apatite and zircon are enclosed in the feldspars.

### Lamprophyric Dikes

A few narrow basic dikes, usually about three feet wide, are found in the gneissoid granite, or granite-gneiss. One of these dikes crosses the

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creek a few hundred feet east of the Crisman depot, and others are exposed in Sunbeam Gulch. The more common variety is a dark aphanitic rock with numerous black patches of hornblende, or hornblende and biotite, in a pinkish, granular groundmass. The dark patches make up nearly half the rock and are from 2 to 5 mm. in diameter. The groundmass contains no mineral identifiable with the unaided eye, except occasional grains of pyrite. The dikes are sharply differentiated from the granite and the rock usually has a gneissoid structure.

Thin sections of rock from a dike crossing Sunbeam Gulch contain no biotite. The hornblende is almost entirely without crystal outline. It appears in irregularly bounded aggregates of individuals intergrown with jagged edges, and also as small flakes in the groundmass. It resembles secondary hornblende in habit. The mineral is pale green and strongly pleochroic. The small flakes constitute probably one-fifth to one-fourth of the groundmass. Augite crystals are present, but rare. The greater part of the groundmass is composed of unstriated feldspar, though microcline occurs in small amount, and occasional soda-lime feldspars are present. The feldspar grains are usually less than .5 mm. in diameter. Kaolinization is common. Among the feldspars an occasional grain of quartz can be detected, but this mineral is perhaps almost negligible in quantity, at least as a primary constituent. Titanite in idiomorphic crystals and rounded and irregular forms is quite common. Apatite and zircon crystals are numerous as inclusions in the feldspar. Epidote is plentiful in grains throughout the rock, and, with pyrite, fills minute fissures.

A specimen from the dike east of Crisman contains biotite intergrown with hornblende in aggregates and scattered throughout the groundmass in the same manner as that of the hornblende noted above. It is yellow-brown in color and strongly pleochroic. Magnetite and hematite are often associated with the biotite as alteration products. Hornblende and the remaining constituents of this dike are identical with those of the rock described above with the exception that the hornblende and biotite are together about equal in amount to the hornblende alone in the other specimens. These dikes have been subjected to metamorphism as the result of intense shearing stresses.

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### Glendale Granite

This rock occurs in irregularly-shaped masses on both sides of Lefthand Canyon in the vicinity of Glendale and Rowena. A good exposure may be seen on the Lefthand Creek road less than one-half mile west of Glendale, and another on the high road about three-fourths of a mile east of Rowena. This rock is probably intrusive into the older biotite-granite described above. Usually the exact contact is not exposed, but underlies a talus-filled depression. This in itself is evidence of an eruptive contact or plane of weakness along which weathering has been more rapid than in either variety of granite. But there is more direct evidence in the inclusion of small masses of the older granite in the younger, and the gneissoid structure of the former near the contact, while the Glendale granite is altogether massive. Furthermore, the Glendale granite sometimes grades into pegmatite near the border, the pegmatite ending abruptly with the gneissoid variety.

The Glendale granite is usually a light-colored rock of which the most striking feature is the great number and character of the phenocrysts. These phenocrysts, which make up nearly one-half the rock, are orthoclase crystals tabular parallel to the clinopinacoid. They are commonly less than 6 mm. thick and are from 1.5 cm. to 4 cm. long. Carlsbad twins, readily seen on cleavage faces in reflected light, are almost universal. Quartz and small amounts of orthoclase and biotite with occasional irregular grains of pyrite compose the groundmass. The biotite is often slightly chloritized.

Under the microscope the biotite does not resemble that of ordinary granite in habit, but is in aggregates of very small flakes. It is doubtless secondary after some primary ferromagnesian mineral which underwent alteration and recrystallization after the magma had come to rest. What this primary constituent was, cannot be determined by an examination of the specimens collected; but it is possible that it was biotite as suggested by the occurrence of primary biotite in small amount, as inclusions in the quartz. The secondary biotite is greenish-brown and strongly pleochroic. Muscovite and chlorite are common alteration products with the separation of magnetite and hematite. Aside from its crystal habit and persistent habit of twinning, the orthoclase

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possesses no peculiarities; there is but very little in the groundmass. Sericite is a common alteration product. The quartz frequently shows undulatory extinction. Liquid inclusions are numerous, often in rows and sometimes as "negative crystals." Minute zircons occur sparingly. In one thin section examined the quartz encloses great numbers of incipient forms of crystallization which do not react on polarized light with the highest powers. They are needle-like and usually under .06 mm. in length. Some individuals seem to be oriented with no relation to others. Again, in the same field there may appear a number of lines intersecting at all angles, and closely resembling a series of dashes drawn with a fine ruling-pen, where each dash represents a crystallite. Or, to make another comparison, they behave similarly to a repeatedly broken column of mercury in a capillary tube. Where disposed in this manner the needles are usually in an absolutely straight line.

### QUARTZ-MONZONITE

North of Lefthand Canyon about half a mile from Rowena this rock is exposed in stocks of which one of the largest is shown on the map. There is another fairly large exposure on the slope of Nugget Hill about a mile northwest of Glendale. The occurrence of several small outcrops between the two leads to the inference that there is a considerable body at no very great depth.

The monzonite is bluish-gray in color and is of fine texture for a phanerocrystalline rock. With the aid of a lens bluish-gray feldspar, a little quartz, numerous biotite flakes usually less than 1 mm. in diameter and small prismatic crystals of pyroxene and hornblende, 2 mm. to 5 mm. long, are seen to constitute nearly the entire rock mass. Rarely, small yellow-brown crystals of titanite can be detected. The total amount of ferromagnesian minerals is quite constant, but locally biotite may decrease and almost disappear as the other dark minerals increase. In the hand specimen it is impossible to distinguish between hornblende and pyroxene. Probably as the result of flow the ferromagnesian minerals tend strongly toward parallelism in planes along which the rock splits readily. The same minerals occasionally segregate in masses commonly less than 1 cm. in diameter.

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At the surface the monzonite is very generally jointed, often in prismatic blocks which stand on end. Not infrequently these are six feet long and may reach a length of ten feet. These blocks usually have the two widest sides parallel, and to be of service as building stone many would require dressing on only the two ends or the two ends and one edge. These longest blocks occur only near the center of the largest stock; near the borders the blocks are much more irregular in shape. The possibility of too frequent jointing, aside from the small "knots," or segregations, which for ordinary purposes are negligible in amount, is probably the only objection to the rock as a building stone. Its fine texture makes it easily workable and practically removes the danger of disintegration through differential expansion. The relatively small amount of ferromagnesian constituents eliminates the probability of excessive iron stain and rapid decay. The color is attractive and but little changed on surfaces longest exposed to weathering. For monumental purposes the monzonite would take a high polish, and on polished surfaces lettering would show distinctly as evidenced by the white edges on trimmed specimens due to minute fracturing of the colorless minerals.

**Microscopic Petrography.**—Feldspar is by far the most important constituent, orthoclase and plagioclase being nearly equal in amount. There is a decided tendency toward idiomorphism on the part of the plagioclase crystals, and zonal structure is pronounced. More calcic zones alternate with more sodic, and three to five bands of each may appear in a single crystal. In sections normal to (010) the highest angle measured was 26°, indicating the presence of labradorite, but it is probable that the greater part of the plagioclase is more sodic than this. The prevailing albite twinning is sometimes accompanied by pericline and less often by Carlsbad twinning. The plagioclase is generally very fresh, but is occasionally kaolinized, and more often saussuritized. In this case the "saussurite" appears to be in large part epidote.

The crystallization of pyroxene, hornblende and biotite was in large part synchronous since intergrowths of any two or all three are present. While the crystallization was in part contemporaneous with the formation of plagioclase, the ferromagnesian minerals did not usually reach

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full development until after the formation of plagioclase was complete. But in one specimen from the margin of the intrusion the pyroxene had taken on crystal boundaries before the plagioclase crystals were fully developed.

Pyroxene and hornblende occur in nearly equal amount, now one, now the other predominant. The pyroxene is probably in large part diopside, though augite may be present. The maximum extinction angle measured from the trace of the prismatic cleavage is 45°. The pyroxene is colorless and without sensible pleochroism. When, as in a few instances, crystal outline appears in cross-section, the prisms and pinacoids are about equally developed. Although the pyroxene is generally allotriomorphic the characteristic prismatic cleavage is often seen. Occasionally this cleavage is accompanied by orthopinacoidal and clinopinacoidal cleavages. Orthopinacoidal twins are not rare, sometimes with the two main parts separated by a lamella in twinned position. Intergrowths with hornblende and biotite are frequent. When pyroxene and hornblende are intergrown the hornblende usually encloses small anhedrons of pyroxene. Sometimes the two minerals are in parallel position, often with a fairly distinct boundary between the two, but irregular in form without the slightest approximation toward crystal outline. It is difficult to decide how much of the hornblende is intergrown with pyroxene and how much is derived from the pyroxene. The former mineral often occurs in small patches in a section of the latter or it may form the greater part of the mass with pyroxene at the center, or in rare cases with pyroxene at both extremities of the anhedron. A single biotite crystal may surround or enclose a pyroxene individual, or the two may interpenetrate with jagged edges. Often several small flakes of biotite, with one or more small patches of hornblende, are attached to the border of a large pyroxene. Sometimes the biotite is scattered in small flakes with parallel orientation over a thin section of pyroxene.

The hornblende is the compact green variety with strong pleochroism and an extinction angle which frequently reaches 19°. Evidences of both primary and secondary origin of this mineral were noted above. Conclusive evidence that the hornblende is in part primary

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is presented by the characteristic crystal outline very rarely seen in cross-sections. Idiomorphism is even more rare than in the pyroxene, and the hornblende not infrequently involves plagioclase crystals in an ophitic manner. In this relation, also, it strongly suggests its primary origin. When biotite is intergrown with hornblende the association of the two is almost identical with that of biotite and pyroxene.

The biotite is brown and strongly pleochroic. Sections inclined slightly to the basal pinacoid give a good uniaxial interference figure. Crystal outline is almost invariably absent. In amount the biotite probably exceeds either of the other ferromagnesian constituents.

The orthoclase is ordinarily allotriomorphic, but occasionally approaches idiomorphic forms, giving a porphyritic aspect to the rock under the microscope. Twinning after the Carlsbad law is but occasionally seen. The orthoclase carries inclusions of all the earlier formed minerals in greater or less number. A single individual may enclose titanite, magnetite, plagioclase and the three ferromagnesian minerals which results in typical micropoikilitic texture. From the contact specimen mentioned above, orthoclase is almost absent. Even in those specimens which show considerable alteration of plagioclase, the orthoclase is nearly always fresh, but occasionally it is slightly kaolinized.

As compared with either plagioclase or orthoclase the amount of quartz is small. It is completely allotriomorphic, having taken the spaces left after all the other constituents had crystallized, with the possible exception that the orthoclase had not entirely crystallized before the quartz began to solidify. It contains numerous liquid inclusions, each with a bubble. Nearly all of these inclusions are elongated and some are perfect "negative crystals."

The monzonite contains titanite in greater amount than does any other rock in the district. This mineral occurs in irregular grains and in perfect crystals. The crystals are usually wedge-shaped, but are occasionally prismatic. Very frequently the titanite is closely associated with small masses of black iron ore. Zircon and apatite are present as inclusions in all the essential minerals of the rock. Magnetite is present in considerable amount in irregular grains enclosed by, or associated with, all the ferromagnesian constituents. Its habit is on

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the whole that of secondary magnetite. Epidote is the commonest secondary mineral next to magnetite. It occurs in small amount with the ferromagnesian minerals that show alteration, and sometimes fills minute fissures which traverse all the minerals of the rock. Scales of chlorite are often present on the pyroxene.

### HYPERSTHENE-DIABASE

Dikes of diabase two or three to seventy feet wide cut both the granite and the metamorphic rocks; they are usually nearly vertical. The strongest dike passes within a mile of Sugarloaf Mountain and extends beyond the area mapped both toward the south and toward the northwest, having been traced approximately ten miles. Since the diabase is more resistant than the granite and metamorphics, the dikes usually stand distinctly, though not prominently, above the country rock and have been a minor factor in shaping the topography. Cubical jointing is universal, the blocks commonly weathering to spheroidal forms. Weathered surfaces are gray to brown, with numerous small black spots due to the fresher surfaces of pyroxene.

The freshest diabase is dark greenish-gray in color. It is a holocrystalline, fine-textured rock the megascopic constituents of which are black pyroxene and an equal amount of olive-green to gray-green feldspar. In color and luster the feldspar closely resembles serpentine Under the microscope black iron oxide appears as a third important constituent.

The feldspar is almost entirely plagioclase with albite polysynthetic twinning, and in many crystals, with the addition of Carlsbad twinning. The feldspars are usually lath-shaped and, for the most part, without regular terminal boundaries. In length they are rarely over 3 mm. From this common type there are two variations: (1) larger subhedral crystals of earlier formation; (2) allotriomorphic untwinned feldspar, probably orthoclase, which crystallized later than the pyroxene. The allotriomorphic variety, very subordinate in amount, is not observable in many slides, nor are the subhedrons common. Since in the zone normal to the brachypinacoid (010) the lath-shaped feldspars frequently give extinction angles of 20°–25° they are probably in large part ande-

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sine-labradorite. Calcite, kaolin and sericite are common alteration products.

There are two kinds of pyroxene present. First, in great amount is very pale brown augite which is faintly pleochroic. The extinction angle measured from the composition plane of the orthopinacoidal twins, which are very common, ranges from 40° to 45°. In a few sections basal parting is distinct. Usually the augite is interstitial between the feldspar laths, generally without a common orientation; rarely it involves the feldspars, producing true ophitic texture. A few crystals have fairly well-defined crystal outline and are idiomorphic toward even the earliest formed feldspar. The augite is often uralitized; and chlorite, black iron ores, epidote, calcite and quartz are common alteration products. Serpentine in fibrous aggregates is often intergrown with chlorite.

A second variety of pyroxene, somewhat less in amount, is orthorhombic. It is pale yellow, slightly pleochroic, and weakly birefringent. Ordinarily it is more nearly idiomorphic than the augite, though it had not always taken on crystal boundaries before the augite began to crystallize. That it is hypersthene instead of enstatite is indicated by the emergence of the optic axes in the macropinacoid (100). Minute inclusions, colorless to brown and opaque, with their long axes normal to the vertical crystallographic axis, are abundant. Although the hypersthene is usually quite fresh it is sometimes changed to bastite, bright yellowish-green in color, with fibers parallel to the vertical axis of the hypersthene. Other alteration products are uralite, or a mixture of uralite and serpentine; frequently serpentine fills fractures passing through the mixture. Sometimes serpentine alone replaces the hypersthene, the process beginning in the cleavage planes. Occasionally small specks of limonite stain the surface of the less altered pyroxene.

By far the greater part of the iron oxide is interstitial, though occasionally euhedrons of magnetite are enclosed in the augite. Much iron ore replaces augite, sometimes retaining the crystal outline. More often it is in irregular masses and skeleton crystals. Occasionally it appears to replace biotite. This ore is either ilmenite or titaniferous magnetite, since material removed from the powdered rock by means

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of a common magnet gives a decided titanium reaction in hydrochloric acid solution.

While quartz is not present in all the slides examined, in many sections there are numerous small irregular masses. In addition to the apatite noted below there are frequent liquid inclusions in the quartz, each with a gas bubble. Although the quartz may be in part primary, there is no direct evidence, such as intergrowth with feldspar. It is without doubt partly secondary, sometimes forming within the boundary of an augite crystal now mostly replaced by iron ore. Since from slides carrying fairly fresh pyroxene quartz is nearly or quite absent, and is most plentiful in those slides which show advanced alteration of the essential minerals, it seems reasonable to infer that most of the quartz is secondary.

Apatite is a common accessory in stout to needle-like crystals included in feldspar, pyroxene, quartz and serpentine. The feldspars contain the greatest number of apatites. Pyrite occurs sparingly in the interstitial feldspar, following the two cleavages. Dark brown biotite was observed in one section in very small quantity and much weathered. In addition to the occurrences of serpentine noted above, it appears in minute patches scattered through the rock, and fills minute fractures in the feldspar.

**Contact Phase of Diabase.**—Near the walls of the dikes the diabase is decidedly finer in texture than that a few feet distant. In the one thin section prepared from this finer-grained variety both the feldspar and the pyroxene are of two periods of crystallization. Minute phenocrysts of augite and feldspar occur in nearly automorphic crystals. The latter have a maximum diameter of 1.5 mm.; the former are usually less than one-half as large. The augite seems to be automorphic toward the feldspar, but in this slide the phenocrysts are too few to warrant the conclusion that the augite is the older. The augites are frequently twinned. The feldspar of the second generation occurs in microlites. Augite is found in the interstices in small grains with serpentine and black iron ore.

In this specimen is a fragment of quartz roughly elliptical in outline with an embayment (Plate III). The longer diameter of the quartz

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is .9 mm. Surrounding the fragment is a band of serpentine probably derived from pyroxene. This band ranges in width from .06 mm. to .35 mm. Bordering the serpentine is a slightly narrower band of minute augite crystals. The embayment is filled with a mixture of granulated quartz and serpentine, and the latter mineral fills two narrow fissures crossing the quartz. No feldspar occurs within the field described. The quartz is doubtless a fragment from the wall rock caught up by the magma before the latter had cooled so far as to preclude corrosion of the inclusion by solution. The quartz, in turn, doubtless effected a slight cooling of the magma adjacent which possibly, if not probably, caused the segregation of the basic mineral within this area.

## TRACHYTE

Trachyte occurs in several narrow dikes, usually less than 20 feet in width. One of the most prominent is exposed on the north wall of Lefthand Canyon at Rowena and has a northerly dip. Another outcrop is seen one-half mile east of Rowena where the dike dips southward. Exposures are commonly weathered to pink or red, and fresh material can be found only in prospect holes. The unaltered rock is light gray to pinkish-white, and contains numerous phenocrysts from 1 mm. to 5 mm. in diameter, besides occasional small grains of pyrite, in a microcrystalline groundmass. The feldspars are white when fresh, but in the weathered rock become pink to black depending on the extent of replacement by iron oxides. In advanced stages of alteration the feldspars may be completely removed. Flow-structure is typically absent. In general the texture and composition are fairly constant throughout the dikes, but a dike south of Fourmile Creek grades from a trachyte near the walls to a more basic rock at the center. This will be mentioned again in connection with the latite of Sugarloaf Mountain.

Under the microscope the feldspar phenocrysts of the typical rock are seen to be almost exclusively orthoclase, some with Carlsbad twinning. Alteration to kaolin is common. Less commonly, mixed with the kaolin, are magnetite and hematite in irregular grains or powder. It is probable that the iron ores are infiltrations from the country rock, since the quan-

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PLATE III

FIG. 1.—Nicols parallel

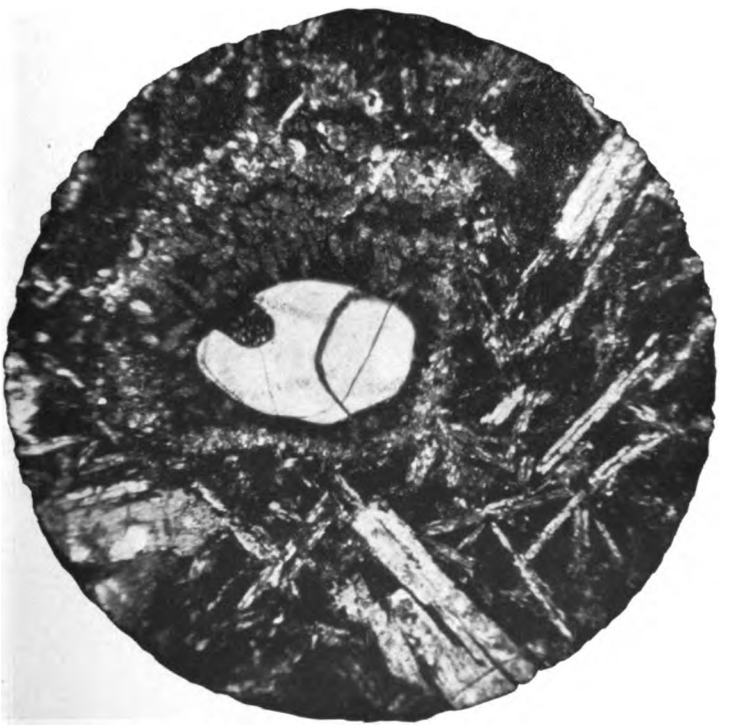

FIG. 2.—Nicols crossed

QUARTZ INCLUSION IN DIABASE NEAR THE DIKE WALL; ×33 (approximately)
PHOTOMICROGRAPH BY MR. G. S. DODDS

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tity of pyrite present is very small and there is no trace of ferromagnesian minerals in the trachyte. The groundmass is composed of multitudes of feldspar microlites with a very little interstitial feldspar, a less amount of quartz and occasional fluorite grains or crystals. Rarely the microlites reach a length of .3 mm. Simple twins and microlites with three lamellae are not uncommon. For the most part the microlites have parallel extinction, but in a few instances extinction angles up to 14° were noted. This comparatively high angle, together with secondary calcite in the groundmass, indicates the presence of some plagioclase. The fluorite is purple and generally in irregular grains, but occasionally shows octahedral outline.

### LATITE

Within the area mapped there is very little evidence as to the relative age of the different dike rocks; but there is no question that the latite is younger than the diabase, since dikes of the former rock are seen cutting the diabase dike south of Fourmile Creek. The latite dikes, as a whole, vary in width from a few feet to 100 feet or more, and present a considerable range in color, texture and mineral composition. Gray is the prevailing color, often of brown shade, rarely bluish. Since no decidedly fresh rock is exposed the original color is unknown, but the tendency in weathering is toward brown tones. In texture the rock ranges from a felsitic phase with a few phenocrysts scarcely 1 mm. in diameter, to a latite porphyry with abundant phenocrysts some of which are 25 mm. in diameter.

The constituent minerals are plagioclase, orthoclase sometimes glassy, biotite, augite and hornblende in varying proportions, beside the accessories titanite, magnetite, apatite, rutile and sodalite or haüynite. The last-named mineral was found in one specimen from the dike west of Long Gulch just north of Fourmile Creek. Here also was found the only rutile observed, in a sagenite web enclosed in altered biotite. In the phenocrystic feldspars plagioclase is commonly in excess of orthoclase. Since the microlites are poorly individualized, it is impossible to determine the relative importance of the feldspars in the groundmass.

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### Sugarloaf Dike[1]

Since the dike passing through Sugarloaf Mountain is the most prominent and least altered, and presents a fairly wide range in mineral composition, the rock will be described in some detail, and this may be taken as a fair average of the latite in general. On the mountain the latite is a brownish-gray aphanitic rock containing megascopic crystals of feldspar, biotite, pyroxene, hornblende and less abundant titanite. Of these the feldspar phenocrysts are the most numerous, usually less than 2 mm. in diameter. They are white, sometimes glassy, and occasionally show striae under a hand lens. The shiny biotite flakes are commonly less than 1 mm. in diameter. It is difficult, if not impossible, to distinguish between the pyroxene and hornblende in the hand specimen. Sometimes crystals of these minerals reach a length of 10 mm., but are for the most part under 3 mm. in length with a thickness of less than 1 mm. Segregations of one or both of these minerals, with which are mingled small grains of feldspar, are not uncommon in masses of several cubic centimeters. Yellow titanite in small crystals with a high luster is a constant accessory. At the top of the mountain the dike is much jointed, prismatic blocks being the prevailing type. Four-sided and five-sided columns are the commonest, but hexagonal forms are not rare. The columns are often long in proportion to the thickness; occasional blocks but 4 to 6 inches thick are 4 feet in length.

Under the microscope the rock is more distinctly porphyritic with phenocrysts of plagioclase, orthoclase, biotite, augite and hornblende. The feldspars are commonly tabular in habit, but sometimes approach equidimensional forms. The ratio of plagioclase to orthoclase is approximately 2 to 1. In the plagioclase albite twinning is frequently accompanied by pericline or Carlsbad twinning. The maximum extinction angle in sections normal to the albite lamellae of 25° indicates that the feldspars are probably not more basic than labradorite with a composition of about $Ab_1 An_1$. Zonal banding is often present, though not pronounced, and different zones are not markedly different in optical properties. Alteration products are calcite, quartz and kaolin. Ortho-

[1] A very careful study of rock taken from the peak was made several years ago by Mr. Barry Hogarty and the results published under the title of "The Andesite of Mount Sugarloaf" in the *Proceedings of the Colorado Scientific Society*, Vol. VI, pp. 173–85.

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clase, like the plagioclase, is often fractured, and like the latter, seldom, if ever, has a good cleavage. Occasionally it exhibits zonal banding, and sometimes Carlsbad twins are present. Kaolin, quartz and sericite appear as secondary minerals in the altered phenocrysts.

Biotite is plentiful, often in hexagonal flakes. It is dark brown in basal sections and gives a uniaxial interference figure. A resorption border with minute grains of magnetite is almost universally present. Magnetite and limonite accompanied by quartz are frequently derived from weathered biotite.

Pyroxene is the freshest ferromagnesian constituent. It is pale green in color and weakly pleochroic. Orthopinacoidal twins are common; these are often seen in cross-sections of the mineral when the nicols are crossed. The high extinction angle, frequently reaching 45°, indicates that the mineral is augite. With the augite are sometimes associated quartz, magnetite and calcite or epidote as alteration products.

The hornblende crystals are often twinned. Extinction angles range from 14° to 19°. Pleochroism is strong, the color ranging from yellowish-green to deep green with a tinge of brown. The crystals almost invariably show a resorption border with minute magnetite crystals. Alteration products are magnetite and quartz, the latter forming near the center of the crystal. Sometimes the groundmass bordering the hornblende is stained by a yellowish substance which is perhaps limonite. Many crystals are completely replaced by magnetite.

Titanite occurs in idiomorphic crystals, sometimes wedge-shaped, again prismatic. The crystals often show rough cleavage cracks, and twinning is common. Apatite is enclosed in all the essential minerals and occurs sparingly in the groundmass. An apparently primary quartz crystal 1.35 mm. in diameter was observed in one section.

The felty groundmass is composed of feldspar microlites with interstitial quartz and possibly feldspar, besides numerous grains of magnetite and much secondary calcite. Although the quartz may be in part primary, much is doubtless secondary. The feldspar microlites are never more than .10 mm. long and are often simply twinned. Since they almost always, if not invariably, give parallel extinction they are doubtless high in alkali. However, the exact extinction angle is deter-

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mined with difficulty, since the microlites are by no means distinct in their boundaries and are more or less altered. Flow-structure may be seen in the freshest specimens, often distinctly showing near the phenocrysts about which the microlites curve.

**Trachytic Phase.**—About a mile northeast of Sugarloaf Mountain, while the dike at the center is only slightly different from that on the peak, it grades toward the walls into a decided trachyte. The dike is exposed in prospect holes and is probably not over 20 feet wide. The latite at the center occupies about one-third of the entire width, and while it is too badly decayed to permit certain identification of all the original constituents, it seems that orthoclase is more important and ferromagnesian minerals slightly less abundant than on the peak. The marginal rock is found in fresh condition in a tunnel driven on the contact with the granite. It contains no ferromagnesian minerals, and apparently differs from the trachyte described above only by the presence of flow-structure and in containing a little more quartz and a few plagioclase phenocrysts and lacking fluorite. This tunnel has also exposed a zone of friction-breccia and friction-conglomerate nearly three feet wide in which the fragments are principally trachyte.

**Nomenclature.**—The following is Mr. Hogarty's analysis of the Sugarloaf rock:[1]

| | |
|---|---|
| Silica | 63.64 |
| Titanium dioxide | .43 |
| Alumina | 18.05 |
| Ferric oxide | 2.14 |
| Ferrous oxide | 1.80 |
| Manganous oxide | .46 |
| Calcium oxide | 3.36 |
| Magnesium oxide | 1.01 |
| Sodium oxide | 3.65 |
| Potassium oxide | 4.73 |
| Phosphoric anhydride | .18 |
| Water | 1.07 |
| | 100.52 |

It appears that the total alkalis and the excess of potash over soda are more characteristic of trachyte than of andesite. Yet the amount of

[1] *Loc. cit.*, p. 181.

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lime is sufficient to class the rock with the andesites, and is too high for a typical trachyte. Before the introduction of the term latite into petrographic literature as a name for rocks intermediate between trachyte and andesite the Sugarloaf rock was probably quite properly called andesite, or according to some petrographers it might have been designated trachytic andesite. But since in the same dike there occurs a a rock which is unquestionably trachyte, and since the rock under discussion has mineralogical and chemical characteristics in common with andesite, and others in common with trachyte, it seems well to consider this dike and others similar as latite.

### Latite-Porphyry

The short east-west dike west of Long Gulch and another about one and one-fourth miles due north of this are the only exposures of latite-porphyry in the area under consideration. The latter dike extends westward where the rock becomes more important both in extent and as a factor in the relief.

The rock is light grey in color, and to the unaided eye appears to be composed almost entirely of idiomorphic crystals of feldspar and hornblende or pyroxene. The megascopic feldspars are largely orthoclase, mostly of the sanidine variety. A striking feature is the large size of the best-developed phenocrysts which are about 25 mm. in diameter. From one to four of these may appear in a hand specimen (3×4 in.). By far the greater number of feldspars are below 10 mm. in diameter, and closely packed. Carlsbad twins, best seen on cleavage faces in reflected light, are not uncommon. Crystals of the ferromagnesian minerals are usually less than 3 mm. in length.

In thin section the smallest feldspars prove to be both plagioclase and orthoclase with the former the more abundant. Augite and green hornblende are both present, the hornblende showing the same resorption phenomena and alteration products as in the latite described above. The groundmass, which constitutes probably one-fourth to one-third of the rock, is composed of lath-shaped feldspar microlites with parallel extinction, and interstitial feldspar. Wedge-shaped titanites and stout zircons occur sparingly.

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Specimens of this rock examined were too few in number to warrant a complete description, and it is possible that more thorough examination of material from exposures toward the west would result even in a modification of the nomenclature.

### HORNBLENDE-ANDESITE

Three-fourths of a mile northeast of Glendale, just within the limits of the map, hornblende-andesite occurs in a single narrow dike. Erosion has exposed the dike but a few hundred feet in a small tributary of Lefthand Creek; westward it passes under the coarse granite and pegmatite which forms the hill. The rock is much jointed, and the surfaces of the joint blocks are weathered to gray or red. The latter color is pronounced only where the hornblende is more or less completely removed.

The fresh andesite shows feldspar and hornblende phenocrysts in a grayish-black lithoidal groundmass. The feldspars are tabular and from 2 mm. to 8 mm. long. They are commonly yellowish-brown as the result of weathering, yet are often highly lustrous. Many of the brownish phenocrysts have cleavage faces which show finely fractured grains of colorless feldspar with vitreous luster. Rarely, with the aid of a lens, distinct striations may be seen on cleavage faces. The hornblende crystals are prismatic in habit, and for the most part under 3 mm. in length but occasionally are twice as long.

Under the microscope the hornblende phenocrysts are seen to be far more numerous than the feldspars. They are of the basaltic variety and usually with well-developed crystal outline and good cleavage. Many of the crystals were broken while the groundmass was still molten but the broken parts are but slightly separated. Resorption phenomena are entirely absent. Pleochroism is strong with a range from dark greenish-brown to yellowish-brown with a greenish tint. The extinction angle is very small and only rarely reaches its maximum of 9°. Orthopinacoidal twins are not uncommon. A few small apatite crystals are enclosed in the hornblende phenocrysts. Magnetite in irregular grains is closely associated with the hornblende but probably only as an alteration product.

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The feldspar phenocrysts are in large part labradorite, but more sodic feldspars may be present. A few of the crystals are unstriated, but albite twinning is common, sometimes accompanied by twinning after the pericline, and less often, the Carlsbad law. Zonary banding is occasionally present. Cleavage cracks are prominent, at times accompanied by fractures which bear no relation to crystallographic directions. Hornblende, apatite and, more rarely, minute zircons are enclosed in the feldspar.

In addition to the secondary magnetite noted in connection with the hornblende, primary magnetite, in octahedrons throughout the rock, is an important accessory. Titanite in perfect wedge-shaped crystals, prismatic forms and irregular grains is fairly common. Rarely the crystals are twinned.

The groundmass is composed of lath-shaped feldspar microlites and minute apatites in a glassy base. Apatite crystals are occasionally included in the feldspars. The microlites are often twinned and have a very low extinction angle which rarely reaches 10°. Flow-structure is often seen in the parallel orientation of the microlites.

## MICA-DACITE[1]

Mica-dacite is exposed in a dike west and southwest of Sunshine Canyon for a distance of about three miles, only part of which is within the area mapped.[2] The maximum width of the dike is not less than 50 feet, but the outcrop in places may be considerably more as the result

[1] Since the following description was written, Mr. Earl B. Millard, a student in the Chemistry Department of the University of Colorado, has made an analysis of the freshest material that could be found in the dike near Sunshine Canyon. The following is Mr. Millard's analysis:

| | | | |
|---|---|---|---|
| $SiO_2$ | 68.07 | $TiO_2$ | 0.26 |
| $Al_2O_3$ | 15.67 | $P_2O_5$ | 0.21 |
| $Fe_2O_3$ | 0.64 | $ZrO_2$ | 0.06 |
| FeO | 2.98 | $CO_2$ | 0.80 |
| MgO | 0.85 | $SO_3$ | 0.23 |
| CaO | 3.32 | BaO | 0.00 |
| $Na_2O$ | 3.45 | SrO | 0.00 |
| $K_2O$ | 2.97 | MnO | 0.00 |
| $H_2O$ | 1.00 | Cl | 0.00 |
| | | | 100.51 |

[2] Mr. Hugh F. Watts, who had carefully plotted this dike on the scale of 6 in. to the mile, generoual allowed me to transfer his work to the accompanying map I am also indebted to Mr. Watts for calling my attention to two exposures of another rock within the area, which otherwise would probably have been overooked.

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of the hade which is sometimes about 45°. Faults of small throw, abrupt bends, and forkings are characteristic features. Jointing in slabs parallel to the walls is common; and flow-structure, best seen in the parallelism of the mica flakes, is pronounced. The same rock occurs in a sheet in the Fountain sandstone exposed in Gregory Canyon southwest of Boulder, on Flagstaff Hill, on the west slope of Red Rock, and east of Sunshine Canyon.[1]

North of Lefthand Canyon dacite of almost identical mineral composition occurs in a dike with a westerly course, which was not traced beyond the limits of the map. Flow-structure, which is so common in the dikes near Sunshine Canyon, is here lacking.

### Petrography[2]

Megascopically this rock shows, when fresh, abundant hexagonal flakes of highly lustrous biotite, occasional flakes of white mica, white to bluish-gray feldspars and less numerous quartz crystals in an aphanitic greenish-gray groundmass. While the biotite crystals vary in abundance from place to place they are everywhere the most numerous of the phenocrysts. In diameter the flakes are usually less than 2 mm. but may reach twice this size. Although they frequently retain their high luster until after there has been considerable weathering of the groundmass they are in most of the exposures chloritized, and have lost their elasticity. The feldspars sometimes reach a diameter of 8 mm. and only occasionally do they show striae under a hand lens. They often appear greenish toward the center of the crystals while the border is white; in an advanced stage of alteration they become pinkish or yellowish, and effervesce readily with hydrochloric acid. The quartz phenocrysts are usually rounded by corrosion, and rarely 1 cm. in diameter. They will average in number from five to ten on one face of a

[1] See *Bulletin 265, U. S. G. S.*, p. 37, map.

[2] Owing probably to the difficulty in finding fresh material for microscopic study and to the apparent rarity of striations on feldspar cleavages in a megascopic examination, this rock has hitherto been regarded as rhyolite or as simply quartz-porphyry. Dr. Palmer and Major Fulton described it under the name of quartz-porphyry (C. S. Palmer, *Proceedings of the Colorado Scientific Society*, Vol. III, pp. 233 ff., and C. S. Palmer and Henry Fulton, *idem*, pp. 351–358). Dr. Fenneman (*Bulletin 265, U. S. G. S.*, p. 36) briefly describes the Sunshine dike and the Flagstaff sheet without naming the rock, but it is designated as rhyolite on the map which accompanies his description.

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hand specimen (3×4 in.). Generally the dacite weathers to a light greenish-gray, but on protected surfaces becomes reddish.

The feldspar phenocrysts so far as observed are found under the microscope to be plagioclase exclusively. Twinning after the albite law is almost universal, sometimes accompanied by pericline, Carlsbad or Baveno twinning. The twinned lamellae are usually very thick. Zonally-built feldspars are very common with a sharp change in the extinction angle from zone to zone. The change is invariably from the more basic variety at the center to less basic toward the margin. One crystal cut approximately parallel to the brachypinacoid (010) gives at the center an extinction angle of 29° from the trace of the basal cleavage, and near the margin an angle of 15°. A difference of 12° was noted between the angle of the outer zone and that of the interior in a section normal to (010). Extinction angles of 25°–35° in the zone normal to (010) are not uncommon, and may be as high as 45°. The largest extinction angle measured from the trace of the basal cleavage on a section approximately parallel to the brachypinacoid was 32°. The frequency of large extinction angles on the brachypinacoid and in the zone normal to that face together with the interference figures and, indirectly, the thickness of the albite lamellae, would indicate a considerable percentage of the anorthite molecule. The plagioclase probably ranges at least from andesine to basic labradorite.

A few of the feldspars are fissured and faulted, the fissure being filled with secondary calcite. Not infrequently the phenocrysts enclose portions of the groundmass, and are sometimes corroded and penetrated by deep bays. The feldspars commonly show alteration near the center of the crystal, less often at the margin. The commonest alteration product is calcite which often has rhombohedral cleavage. Sometimes in advanced stages of weathering chlorite accompanies calcite. A less frequent product is epidote accompanied by sericite. Kaolin is very subordinate in quantity.

Biotite was the first of the three essential constituents to crystallize, since it can be seen, though not often, penetrating both the quartz and feldspar and occasionally enclosed in the feldspar. Sometimes the biotite crystals were broken and torn apart while the magma was still

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in motion. Again the mineral appears in minute flakes apparently pseudomorphous after pyrogenetic biotite, since aggregates of these flakes have the same outline as the biotite crystals in other specimens. This secondary biotite must have formed after the magma had come to rest. Ordinarily the biotite is yellow-brown in basal sections and gives a uniaxial interference figure. In the freshest specimens the flakes often suggest resorption by the presence, on the border, of minute grains of an opaque substance probably magnetite. Often the biotite is completely replaced by epidote and chlorite with a small amount of magnetite, less often by muscovite and chlorite with some magnetite. Muscovite phenocrysts are few in number and are, at least in part, secondary after biotite.

The quartz phenocrysts are invariably corroded and embayed. It is quite probable that in the last stages of phenocrystic development resorbed silica from the quartz phenocrysts furnished the acid necessary to the formation of the more sodic feldspars which form the outer zone of the plagioclase phenocrysts. Inclusions of groundmass are present in nearly every quartz examined. Occasionally a part of the phenocryst has been torn from the parent crystal and the interspace filled with groundmass. Liquid inclusions are abundant, sometimes in rows, oftener irregularly distributed.

**Groundmass.**—This is composed of small grains of unstriated feldspar, minute flakes of muscovite, scattering grains of magnetite, occasional zircons and, in a few specimens, small apatites. In addition there are in some sections minute prismatic crystals strongly resembling apatite, but too small to identify. The magnetite is in irregular grains in the dacite near Sunshine Canyon, but in octahedrons and dodecahehrons in the Lefthand variety where it is probably primary. In the altered rock secondary calcite is abundant. The only apparent difference between the dacite north of Lefthand Canyon and that near Sunshine Canyon, in addition to the absence of flow-structure from the former and the presence of euhedrons of magnetite, is the somewhat coarser texture of the same variety.

**Accessories.**—In addition to the isolated crystals noted above small zircons are enclosed in all the phenocrystic minerals with the possible

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exception of muscovite, and are also found in the calcite which replaces the feldspar. Small apatites are present as inclusions in quartz, feldspar and mica phenocrysts. Primary magnetite probably occurs only in the groundmass.

### RHYOLITE (FELSITE)

Field relations indicate that this rock is later than the mica-dacite. Nowhere within the area covered by the map do the dikes intersect, but in Sunshine Canyon, about a mile from the western limits of Boulder, dikes of the two rocks are in contact and parallel for several hundred feet. Along the contact the rhyolite has been intruded into narrow fissures in the dacite; less often the later rock has caught up fragments of the dacite, producing a breccia which is largely cement.

The rhyolite dikes are generally narrow (10–30 ft.), but one dike near Crisman has a width of 60 feet at one point. Exposures are often not continuous. Moreover a dike may abruptly change its course, it may fork, or it may be interrupted and continue its course, as an offset. In color and texture the rock closely resembles the Leadville "white porphyry," but it does not break into blocks under the hammer as does the Leadville rock. White when fresh, it weathers often to a greenish cast, and in places to pink. Concentric bands of pale brown at various distances apart are not uncommon. The last product of decay is a white clay which, as well as the less altered rhyolite, has been used to a small extent in the manufacture of buff brick.

Jointing is almost universal, but of different types. Prismatic jointing with rectangular blocks is often seen, but this may give way within a short distance, to jointing in which the only regular planes are parallel to the walls of the dike, producing slabs and plates often a small fraction of an inch in thickness. Dark brown or black dendrites, oxide of manganese or a mixture of manganese and iron oxides, are often present.

**Petrography.**—The rhyolite carries a few megascopic crystals of quartz, feldspar, mica and rarely pyrite in a white felsitic groundmass. Not all of these minerals are likely to be found in a single specimen. Quartz and mica are probably the commonest, while in many specimens

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there is no recognizable mineral. The quartz and feldspar phenocrysts are rarely over 3 mm. in diameter; the mica crystals are usually smaller, but occasionally have a diameter of 5 mm. Although the mica crystals are almost black, thin cleavage plates are transparent and colorless.

In thin sections the rock is seen to be almost entirely groundmass which is microcrystalline and which may carry phenocrysts of one or more of the above-named minerals. From some slides phenocrysts are absent. Both orthoclase and plagioclase are present, the latter in less amount than the former. The plagioclase has a maximum extinction angle of 20° in the zone normal to the brachypinacoid. It commonly shows alteration to sericite and calcite. Some orthoclase phenocrysts show advanced alteration to muscovite, while others are completely replaced by kaolin. The brilliantly polarizing muscovite in phenocrysts may possibly be primary, but in a rock so much altered it is quite as likely to be a result of the leaching of biotite. No phenocrysts of quartz were present in the slides examined.

The groundmass is an intimate mixture of poorly individualized grains of quartz and feldspar in which are embedded lath-shaped feldspar microlites and flakes of muscovite. The feldspar microlites are never more than .10 mm. long, and often are once twinned; rarely three lamellae are present. They are frequently kaolinized or sericitized, and sometimes calcite accompanies alteration. While muscovite may be in part a primary constituent it is doubtless largely an alteration product of the feldspars. In addition to its being intimately mixed with small grains of feldspar, quartz occasionally occurs in irregular masses about .2 mm. in diameter. These grains bear no resemblance to phenocrysts and were probably the latest product of crystallization, if not of secondary origin. Irregular bands of minute brown specks seen under high powers doubtless represent the dendrites of oxide of manganese. No flow-structure is apparent.

## AGE OF DIKE ROCKS

There are no criteria by which the age of the dikes can be determined, except within very wide limits. These rocks are considered to be Tertiary eruptives, along with others of the Front Range which

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supplied pebbles for the Denver formation. In the vicinity of Boulder the only direct evidence is found in connection with the rhyolite and dacite. The rhyolite, which is perhaps the youngest dike rock of the district, overlies the Niobrara and Pierre shales in several exposures.[1] This relation shows it to be at least as late as Upper Cretaceous. The dacite on Flagstaff Hill was intruded before the last crustal disturbance, since slickensided dacite at the contact with the sandstone is often present, and thus furnishes evidence of differential movement after the sheet had solidified.

[1] *Bulletin 265, U. S. G. S.*, p. 39.

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# STUDIES IN LAKE AND STREAMSIDE VEGETATION

By Francis Ramaley and W. W. Robbins

## I. Redrock Lake near Ward, Colorado

Page

I. Topography and Geology. *Location, Glaciation, Boundaries, Water Level, Shore and Bottom, Comparison with Other Lakes* . . . . . 135

II. Climatology. *General Statement, Temperature Records, Length of Growing Season, Inversion of Temperature, Daily Range, Insolation, Rainfall, Relative Humidity, Wind, Comparison with Climate of Other Stations* . . . . . 138

III. Soil Temperature and Moisture. *Observations of Soil Temperature. Soil Moisture Observations* . . . . . 147

IV. Zonation. *General Account, Previous Lake Studies, List of Species Collected from the Different Zones, Lake Zone, Sedge Zone, Forest Zone, Arenaria Associations, Dasiphora Associations, Aspen Association, Dense Dry Forest, Open Dry Forest, Moist Forest* . . . . . 148

V. Seasonal Aspects. *General Account, The Seasonal Limits, Spring Aspect, Summer Aspect, Autumn Aspect* . . . . 159

VI. Floristics and Distribution. *General Account, Systematic List by Families, Altitudinal Range of Species, Extension of Altitudinal Range, Geographical Range of Families, Genera and Species* . . . . . 161

VII. Summary . . . . . 167



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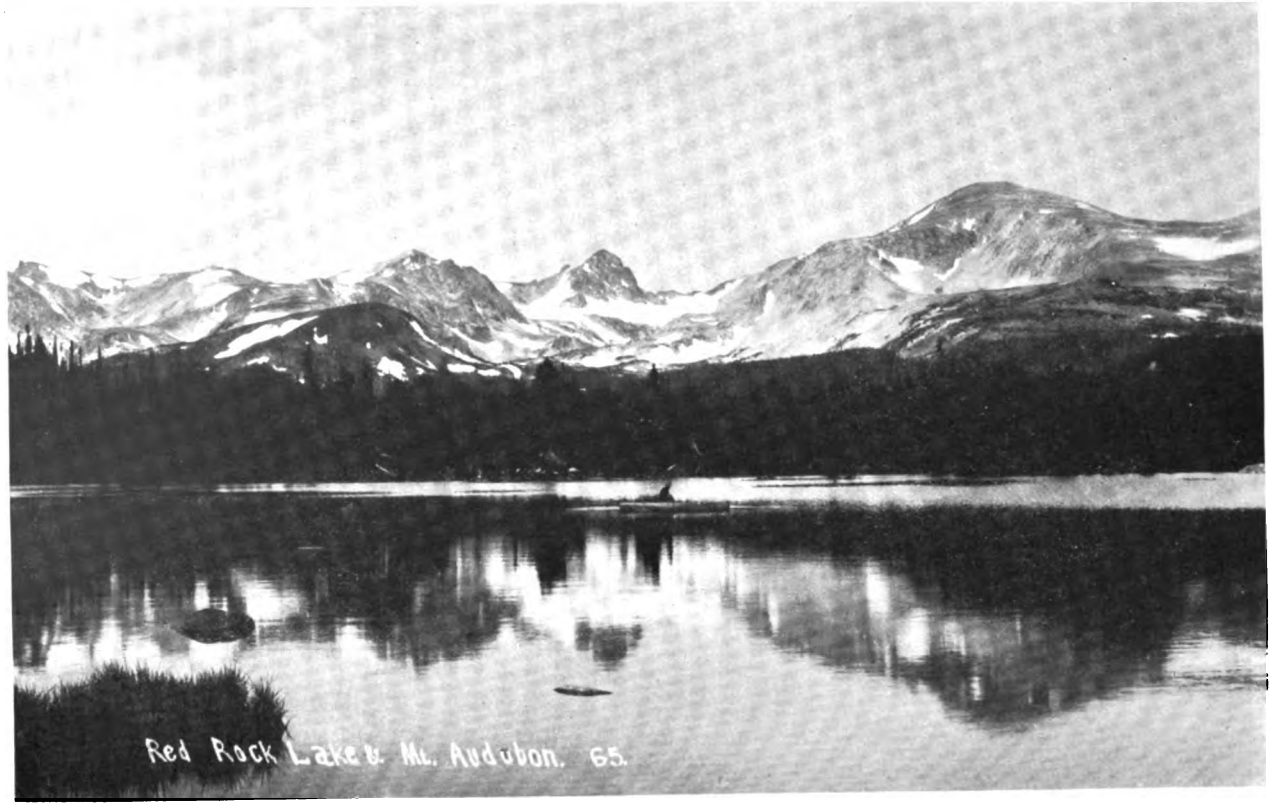


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# REDROCK LAKE NEAR WARD, COLORADO[1]

## I. Topography and Geology

**Location.**—Redrock Lake is located in Boulder County, Colorado, about 2½ miles (4 kilometers) west of Ward, in the drainage of the South St. Vrain Creek, longitude 105° 30′ W., latitude 40° 05′ N. It has an altitude of 10,100 feet (3,080 meters). The continental divide is about 3 miles (5 kilometers) west of the lake, this distance being much less than that of most localities at the same altitude.

**Glaciation.**—During Pleistocene times many parts of the mountains of Colorado were glaciated. In the region studied glaciation is very evident. The glacier extended to some distance east of Redrock Lake and down to an altitude of about 9,300 feet (2,843 meters). Glacial action and subsequent erosion have formed a topography consisting in general of a series of morainal ridges running parallel with and at various angles across the longitudinal axis of the valley. Redrock Lake lies in a depression between such morainal ridges.

**Boundaries.**—On the lower side of the lake is a morainal ridge about 9 meters (30 feet) high. This ridge swings around and connects with one on the south of the lake about 23 meters (75 feet) high, and one on the north about 3 meters (10 feet) high. To the west is a low ridge separating the lake from a wet meadow. The E-W and N-S cross profiles (see Figs. 2 and 3) of the lake give the relative steepness

[1] Colorado, with its mountains and plains, offers exceptional opportunities for the study of lake and streamside vegetation. Lakes are abundant on the plains and in all the mountain zones, up to and including the alpine zone. The streamside vegetation of a single stream may be studied with profit by following it from ts head, in alpine regions, through the sub-alpine, montane, foothill and finally into the plains zone. In the study of the lake and streamside vegetation of a mountainous region it is possible to make valuable comparisons of species peculiar to certain habitats as influenced by climatic conditions. Edaphic and climatic factors, in their various relations to each other, can be studied with much satisfaction.

The present study, the first of a series, is concerned with the vegetation of a single lake which is typical of the sub-alpine region. The writers have under observation and have collections from about twenty-five akes and ponds at various places in Colorado. These lakes range in altitude from 5,000 to 12,000 feet (1,530–3,660 meters). The intention is to make comparisons of the vegetation in and about these lakes and also with that of lakes studied by others. Various ecological stages and different geologic types are represented; thus conditions are favorable for the study of the relations of the plant formational changes to the physiographic changes and the interaction of different plant associations upon each other.

Collections and studies of streamside vegetation have been carried on the past season. This work will be continued from year to year in connection with the study of lakes.



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of the morainal ridges on the four sides of the lake. The ridge to the south separates the lake from Bog Lake, a small glacial pond in about the same ecological stage. Bog Lake is higher than Redrock Lake; the outlet from it does not flow into Redrock Lake, however, but into the wet meadow to the west. Redrock Lake has no stream inlet;

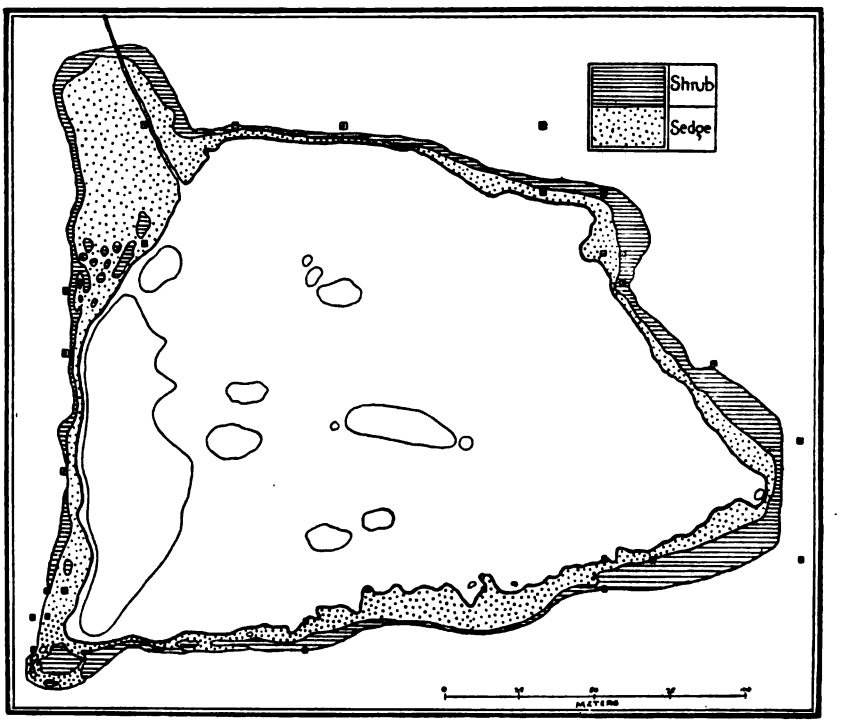


FIG. 1.—MAP OF REDROCK LAKE SHOWING PLANT ZONES

The enclosed areas in the lake are groups of water lily leaves; dotted areas represent sedges; horizontal shading represents shrubs. Outside of the shrub zone is forest, the exact character of which is discussed in the account of zonation. The small squares, each with a dot in the center, indicate stakes or stations used in making the survey.

it receives its water supply by seepage, mainly from the wet meadow and from the run-off of the bounding moraines. The outlet is at the northwest side through the low north ridge (see Fig. 1).

**Water Level.**—In the spring and early summer the lake is usually overflowing but in the late summer and autumn little or no water leaves

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the lake through its outlet. The fluctuation in the level of the lake from year to year and from season to season is slight and does not seem to be of much importance in its relation to the rate of filling.

**Shore and Bottom.**—Redrock Lake measures about 180 meters (590 ft.) across from east to west and 120 meters (394 ft.) across from

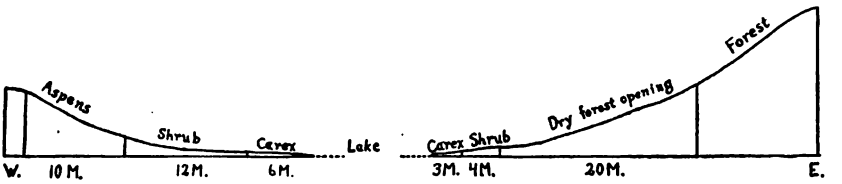


FIG. 2.—EAST-WEST PROFILE OF REDROCK LAKE

The greater width of the sedge and shrub zones on the west is accounted for by the fact that there is a considerable amount of seepage water through the low aspen-covered moraine from the wet meadow to the west. The dry-forest opening on the east of the lake is discussed under the head of Arenaria Associations in the account of zonation.

north to south. It varies in depth from a few centimeters to 1.5 m. (6 inches to 4 ft.). Large morainal boulders project above the water level in places. The west two-thirds of the lake has a mud bottom;

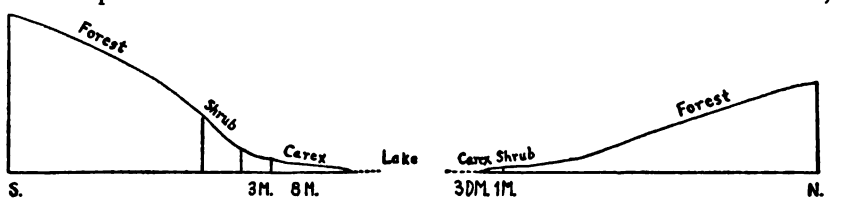


FIG. 3.—NORTH-SOUTH PROFILE OF REDROCK LAKE

The moraine on the south is relatively much steeper than the one on the north. While the crest of the north moraine is shown in the figure, the crest of the moraine on the south extends beyond the limits of the figure and is much higher than is shown. The steep south moraine furnishes a great amount of seepage water to the lake and the run-off brings wash material to the lake edge; these conditions, along with the fact that the lake shore here is well shaded, account for the much wider zones on the south than on the north side of the lake. The north-bounding moraine is low and has a gradual slope to the lake; hence there is an accumulation of but little wash material about the lake edge. Furthermore the shore is well exposed to the sun and soon dries out.

here we find patches of water lilies. The remainder of the lake-bottom is stony and covered over with a fine layer of silt.

Around the edge of the lake is a marginal rim, in some places .6 m.

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(about 2 feet) high. (See Fig. 8.) This rim is made up of loose, spongy soil composed largely of organic material. Farther back from the lake in the outer part of the sedge zone and in the shrub zone, the soil becomes more compact, freer of organic material and assumes a clayey character. On the south side of the lake, a thick growth of moss in the shrub zone makes a spongy surface layer. The forest zone is restricted to the morainal ridges. These are made up of a coarse material and are very thinly covered with drift. This shallowness of soil is due to rapid run-off and partially accounts for the number of uprooted trees and for the openings in the forest where trees have fallen.

**Comparison with Other Lakes.**—In level areas, such as are found on the plains of Colorado or prairies of the middle states, the zones about the lakes are much wider than they are about mountain lakes. In the case of level-country lakes the general run-off is slow, consequently a fine soil can accumulate along the shore. Seepage water from the lake works its way out through the soil of the shore, is held by the fine soil and thus forms a wide marshy area. On the other hand, in the case of Redrock Lake and many other bodies of water in mountain districts, the general run-off about the lake is rapid. This condition prevents the accumulation of a fine soil about the lake and so the seepage water in the soil at the lake margin is quickly carried away and does not produce an extended marshy area. It will be seen (see Fig. 1) that the plant zones on the north side of the lake are particularly narrow. Here the lake is bounded by a low moraine, which slopes gradually toward the shore (see Fig. 3), so that there is but little wash material carried to the lake edge.

## II. Climatology

**General Statement.**—No weather records are available for Redrock Lake except those made by the present writers during the summer of 1908. A Draper thermograph was kept running during June, July and August, trips being made weekly from Boulder, thirty miles away, to change the records. The instrument was housed in a suitable shelter (see Fig. 12) with slat sides and was located about 100 meters (320 ft.) east of the lake on ground two meters above the level of the lake. A

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pair of evaporimeters was also set up and readings taken for a few weeks. At points distant 10 miles (16 km.) or more from Redrock Lake there have been "voluntary observers" who made records of temperatures and precipitation for short periods but these records are so

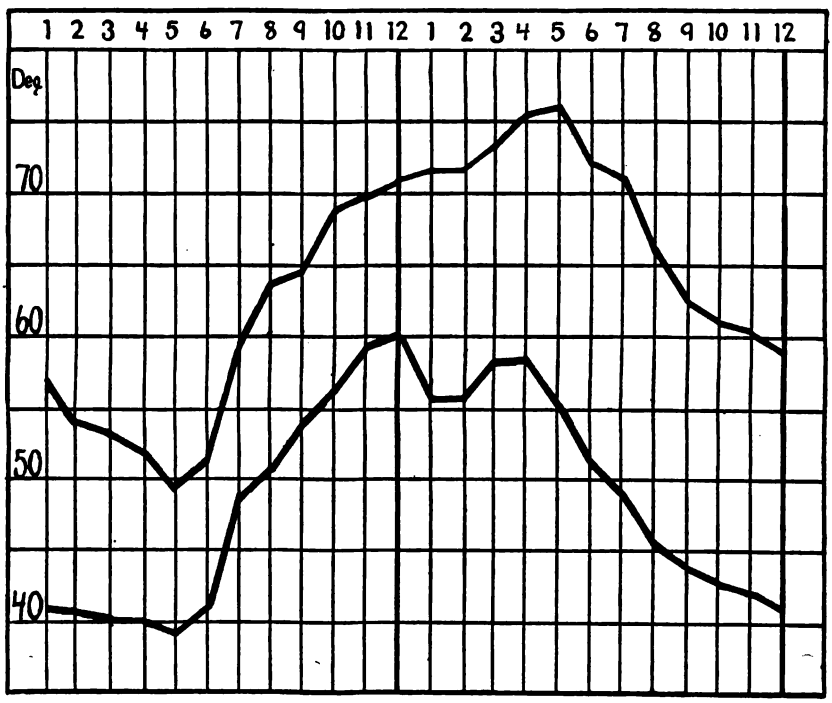


FIG. 4.—MEAN MARCH OF TEMPERATURE BY HOURS FOR THE WEEK ENDING AT MIDNIGHT JUNE 28, 1908.

The upper line is Boulder, the lower, Redrock Lake. The temperature shown for each hour is the mean for the seven records of that hour. It will be noted that the minimum temperature at both stations is reached at 5:00 A. M. At Redrock Lake the maximum is at 12:00 M. with a depression at 1:00 and 2:00 P. M. due to the thunder showers which occurred nearly every day during the week. The flatness of the Boulder curve at the corresponding hours is the result of temporary clouds which often appear in the early afternoon even when there is no shower.

incomplete and probably so unreliable that they cannot be used.[1] Something of the climate may be inferred from what is known of other

[1] Some fragmentary observations on air and soil temperatures in the mountains of Boulder County are given in an article by ROBERT T. YOUNG in the *Botanical Gazette*, Vol. XLVI, pp. 321–52, 1907.

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high-altitude stations in Colorado. Various comparisons are made in the following pages.

**Temperature Records.**—The records of the Draper thermograph at Redrock Lake taken during the summer months of 1908 furnish a very complete picture of temperature conditions for the growing season.

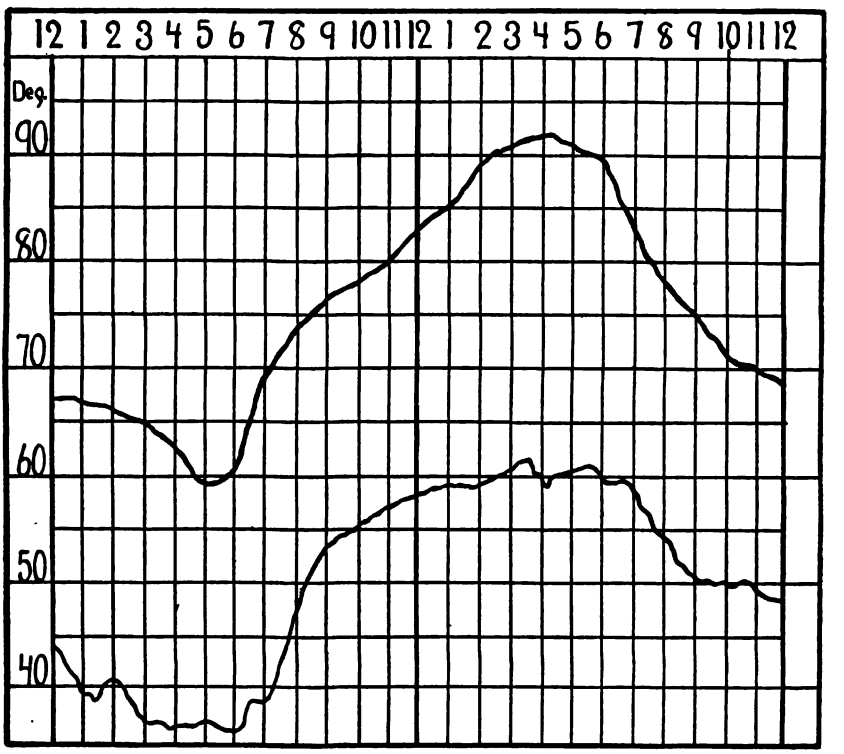


FIG. 5.—COPY OF THERMOGRAPH TRACINGS FOR AUGUST 28, 1908, THE HOTTEST DAY OF THE YEAR.

The lower line (Redrock Lake) is seen to be much more wavy than the upper (Boulder) illustrating the fluctuations of temperature so characteristic of mountain climates.

Since another set of records was made in Boulder at the same time useful comparisons are possible. In 1908 June, July and August at Boulder all showed monthly means about two degrees below normal so that it is probable that temperatures at Redrock Lake were also somewhat below normal. Examination of Table I shows a mean difference each

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month of about 15 degrees Fahrenheit in the two stations. Since the altitudinal difference is about 4,700 feet (1,430 meters) this means an average depression of temperature of 3.2 degrees F. for each 1,000 feet (6.5 degrees C. for each 1,000 meters) of altitude.[1] A comparison of the records of the observer at Idaho Springs, Colo., which is 40 km.

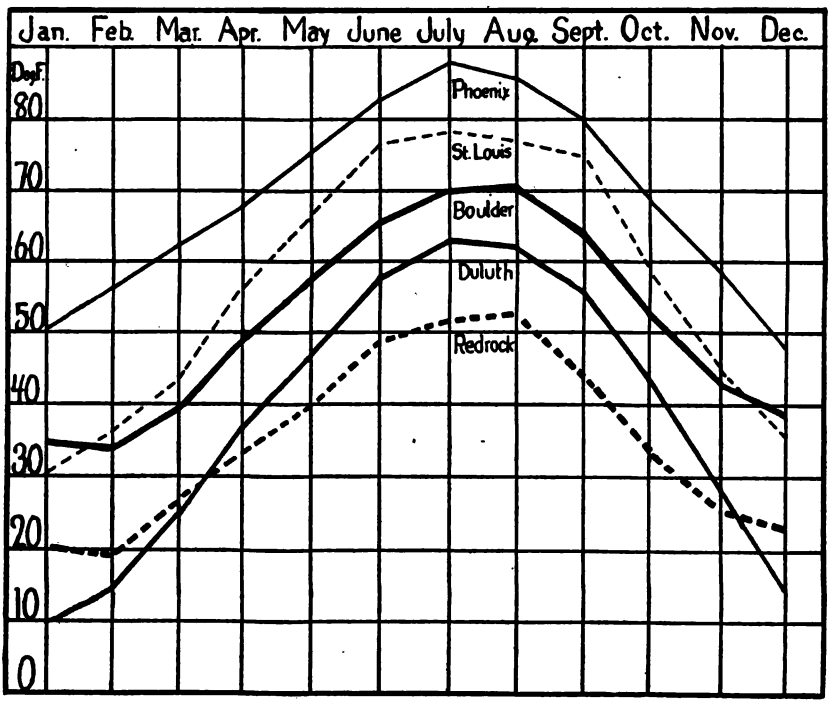


FIG. 6.—GRAPHIC REPRESENTATION OF THE MEAN TEMPERATURE BY MONTHS AT PHOENIX, ARIZ., ST. LOUIS, MO., BOULDER, COLO., DULUTH, MINN., AND REDROCK LAKE, COLO.

Particularly noticeable is the low summer temperature at Redrock Lake. In connection with this figure the reader should consult Table II. A description of the method employed in preparing the Redrock Lake curve is given in the text.

(25 miles) south of Redrock Lake, but at a lower altitude, shows a difference of about 10 degrees F. for the summer months of 1908. The

[1] The observations of De Saussure in the Alps showed a depression of about 6.3 degrees C. for each 1,000 meters. Hence conditions at Redrock Lake may be taken as quite normal for mountain regions. De Saussure's figures, together with others from various investigators in different parts of the world, are given by HANN, pp. 243–45. (See the following note.)

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records of the observer at Long's Peak station, also at an altitude below that of Redrock Lake, seem to correspond fairly well with those at the lake. In preparing a problematical temperature curve for Redrock Lake the data from Idaho Springs, Boulder and Long's Peak were used with proper allowance in case of the first two. It is believed that the curve presented in Fig. 6 indicates very nearly the mean temperature by months at Redrock Lake. It is impossible to state, with the data at hand, whether there is the same difference in winter and summer between Boulder and Redrock Lake. As a rule in mountain regions the high-altitude stations do not show relatively such low temperatures in winter as in summer.[1] In a study of temperatures at Lake Moraine and at Colorado Springs, Loud[2] found the difference in temperature during winter was 11.7 and in summer 16.1 degrees.

**Length of Growing Season.**—This may be very short. Thus in 1907 at a station (altitude 8,600 ft. or 2,620 meters) near Long's Peak the date of last frost was July 16 and of earliest frost in autumn, Aug. 11, leaving a period of less than one month without frost. Since, however, there is a greater daily range of temperature at the Long's Peak station it is likely that these figures would not be quite applicable to Redrock Lake. Probably, as a rule, five or six weeks in the middle of summer are without frost. This short time does not, however, represent the entire growing season since the plants are all such as can withstand light frosts. Other plants of the lowland districts would be unable to exist there.

**Inversion of Temperature.**—It is believed that temperature inversion is not a factor of consequence at Redrock Lake. The temperature at the shore of the lake is probably almost the same as that of the moraines which shut it in. No doubt it is a very few degrees colder at night but the day temperature is the same. In steep gulches it is probable that temperature is of greater consequence as is shown by the marked difference in the flora of the sides and bottoms of gulches. In making a preliminary study of this subject one of the writers made observations for a week during August in a gulch of Beaver Creek about 5 km.

[1] HANN, *Handbook of Climatology* (Ward's Translation), p. 246, 1903.

[2] LOUD, *Colorado Sky*, Vol. I, p. 8, 1908.

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(3 miles) north of Redrock Lake. Here an average difference of 10 degrees was noted in the temperature of gulch and ridge at night, the gulch being the colder.

**Daily Range.**—It is shown in Table I that the daily range of temperature is less at Redrock Lake than at Boulder. Most persons acquainted with high altitudes believe that the range there is much greater than at lower points. It is probable that this misconception is due to the fact that the sun temperature at midday is high in mountain districts and people think of that rather than of the shade temperature in forming their opinions of the climate. One reason for the smaller daily range at Redrock Lake is the frequent clouding up in the afternoon. If there is no afternoon shower the range may be nearly as great as at Boulder. The clouds of afternoon are probably of some importance to plants, especially to those in dry soil. The direct heat of the sun is very great and relative humidity is low during the day. Plants which are barely able to get water to replace that transpired may be saved by the afternoon clouds from death by wilting. It is certainly true that many apparently mesophytic species are able to live in the dry forest and this almost daily clouding of the sky in the afternoon may be of consequence in this regard. The chart, Fig. 4, made by combining hourly records for the week ending June 28, 1908, shows the mean hourly march of temperature for that week at Redrock Lake and at Boulder. The depression which occurs between 12:00 M. and 1:00 P. M. at Redrock Lake keeps the maximum low and gives the curve a more flat appearance than that showing the temperature at Boulder.

**Insolation.**—Direct heat of the sun is very great at high altitudes and the difference between sun and shade temperatures is often remarked.[1] No suitable instrument is known to the writers which may be used for measuring this ecological factor. The black bulb thermometer is, according to Hann, open to serious objections. Insolation is supposed to be one of the causes for the dwarfing of alpine plants but it is to be noted that such true alpine plants as grow at Redrock Lake have just the same habit and appearance there as in the much higher regions where insolation is greater. The great metabolic activity of high-

[1] SCHIMPER, *Plant Geography* (English Translation), pp. 692, 693, 1903.

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altitude plants by means of which they are able to complete a season's growth in a few weeks is to be accounted for by increased chemical intensity of sunlight. Where there is little moisture in the air and little dust the sunlight is intense as soon as it reaches the plants in early morning and again in late afternoon. Hence in effect the day is longer for these plants than for the plants growing down on the plains.[1]

**Rainfall.**—No data concerning rainfall are at hand. It is, however, probable that the annual precipitation is about 760 mm. (30 inches). This estimate is made after comparison with a number of rainfall records from various parts of Colorado. Snows are heavy and drifts remain in protected places until late June. The presence of certain particular species forming patches of vegetation here and there through the forest is only understood when it is known that snowdrifts regularly lie in those situations. A large patch of *Sibbaldia* just beyond the moraine east of Redrock Lake is able to live there because of the immense snowdrift which furnishes moisture during the spring and early summer. This high ground would otherwise be quite dry (see Fig. 11).

**Relative Humidity.**—Very little can be said in regard to relative humidity. As is well known, this varies greatly, even during a few minutes, in high altitudes. Probably it is somewhat lower than in the foothills and plains.[2] The general lower temperature of the higher points, as Redrock Lake, and the greater rainfall, more than compensate

[1] HANN, *Handbook of Climatology* (Ward's Translation), pp. 235, 236.

[2] This is particularly true during the day. The following data of August 8, 1908, illustrate the point. Stapp's Lake, where the observations were made, is about three miles north of Redrock Lake at an altitude of 9,400 feet.

| | Boulder 5,400 ft. | Stapp's 9,400 ft. |
|---|---|---|
| Highest relative humidity | 84 | 100 |
| Lowest relative humidity | 52 | 28 |
| Range for the day of 24 hours | 32 | 72 |
| Mean relative humidity for the 24 hours | 67 | 64 |
| Mean relative humidity, hourly observations from 6 A. M. to 6 P. M. | 60 | 37 |

While the mean relative humidity for the entire day was not very different for the two stations the daily range was much greater at the mountain station; the day was drier and the night more moist. August 8, 1908, was a typical hot summer day in Boulder with very little wind and no thunder shower. Conditions at Stapp's Lake were similar. The highest temperature recorded at Boulder was 89 degrees and at Stapp's Lake 72 degrees.

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for any special dryness of the air and evaporation is slower than at lower altitudes. This fact was clearly shown by the fragmentary records of the evaporimeters maintained in a forest opening east of the lake for a period of a few weeks.

TABLE I. TEMPERATURES AT REDROCK LAKE AND AT BOULDER, COLO., FOR 1908
(*Degrees F.*)

| | | Redrock Lake | Boulder* | Difference |
|---|---|---|---|---|
| Mean Temperature | June | 46.5 | 62.2 | 15.7 |
| | July | 52.3 | 67.6 | 15.3 |
| | Aug | 51.4 | 65.6 | 14.2 |
| Mean Minimum | June | 35.0 | 48.7 | 13.7 |
| | July | 40.9 | 55.7 | 14.6 |
| | Aug | 41.6 | 54.0 | 12.4 |
| Mean Maximum | June | 58. | 75.6 | 17.6 |
| | July | 63.6 | 80.1 | 16.5 |
| | Aug | 61.2 | 77.3 | 16.1 |
| Absolute Minimum | June | 26. | 41. | 15. |
| | July | 30. | 45. | 15. |
| | Aug | 34. | 46. | 11. |
| Absolute Maximum | June | 70. | 91. | 21. |
| | July | 63. | 93. | 30. |
| | Aug | 73. | 92. | 19. |
| Mean Daily Range | June | 23. | 27. | 4. |
| | July | 22.7 | 24.4 | 1.7 |
| | Aug | 19 6 | 23.3 | 3.7 |
| Last Frost in Spring | | July 7 | May 21 | 47 days |
| First Frost in Autumn | | Sept. 1 | Sept. 26 | 25 days |
| Period without Frost | | 56 days | 128 days | 72 days |
| Mean Annual Temperature | | 36† | 50.9‡ | 14.9 |

* At University campus.
† Estimated (see p. 142).
‡ Government Record, 11 years.

**Wind.**—From a botanical standpoint wind is of interest chiefly because of its effect on transpiration. There can be no doubt that winds at Redrock Lake are high, especially in winter. The dwarfed and contorted "wind timber" at the east of the lake is sufficient evidence on this point. In summer, so far as the writers could judge without the use of instruments, the winds are no more severe than at lower altitudes. Hence the influence of high wind is exerted on the shrubs and trees which are exposed in winter and not upon the herbaceous vegetation. The trees, especially, show wind influence in their dwarfed form and profuse branching and slow growth. The shrubs, where exposed to high wind,

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are somewhat more branched than elsewhere but seem not to be dwarfed. All of the species of *Salix* and the single *Betula* are present on the windy east shore quite as much as in the protected parts at the west end of the lake. The single species of *Lonicera* does not occur along the windy shore. Among trees the limber pine is more abundant in windy places but as these situations are more dry it may be that the distribution of this pine is not related to wind but to soil dryness and that it grows only in the areas not otherwise occupied. In these dry places the limber pine has an opportunity to grow because there is no competition of Engelmann spruces. These latter trees regularly frequent the moister soil. In view of what has been said it is safe to conclude that wind is of a very secondary importance to the vegetation except in its effect upon the development of "wind timber."

**Comparisons with Climate of Other Stations.**—The climate of Redrock Lake is distinctly cool. During the summer months the temperature is 25 degrees lower than at St. Louis, 10 degrees lower than at

TABLE II. SUMMER TEMPERATURES AT REDROCK LAKE AND AT CERTAIN FAR NORTHERN STATIONS (*Degrees F.*)

| Station | June | July | Aug. |
|---|---|---|---|
| Ft. Conger,* Grinnell Land, 81° 44′ N., 64° 45′ W. Alt. *sea level* | 31.0 | 36.5 | 33.4 |
| Ft. Churchill,† Hudson Bay, N.W.T., 58° 51′ N., 94° 11′ W. | 42.0 | 52.3 | 51.0 |
| Redrock Lake, Colo., 40° 05′ N., 105° 30′ W., Alt. 10,100 ft. above sea level | 46.5 | 52.3 | 51.4 |
| Banff, Alberta,† 51° 10′ N., 115° 34′ W. Alt. 4,542 ft. above sea level | 49.7 | 58.4 | 56.8 |
| Dawson, Yukon,† 64° 4′ N., 139° 20′ W., Alt. 1,200 ft. above sea level | 59.2 | 59.3 | 55.3 |

* SCHIMPER, *Plant Geography* (English Translation), p. 667. 1903.

† *Report of the Meteorological Service of Canada* (1905), published 1907. [Banff is the highest-altitude station in the Rocky Mountains of Canada where records are made.]

Duluth, Minn., and even 8 degrees lower than Dawson, Yukon (cf. Fig. 6 and Table II). The summer climate is by no means arctic as is shown by Table II, in which a number of comparisons are made. Winter temperatures are probably not very low, perhaps such as would occur at Chicago, Ill., or Albany, N. Y. It is certain that the winters are far warmer than at St. Paul or at Duluth, Minn. In precipitation, with about 760 mm. (30 inches) per annum, Redrock Lake has a lower annual

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rainfall than mountain stations in the Appalachian region but there is much more rainfall than in the foothills and plains regions of the Rocky Mountain area. It may be said that the climate of Redrock Lake is highly unfavorable for the growth of plants except such as can exist with a very small amount of total heat for the growing period. It would be quite impossible to grow even the hardiest grains because of the general low summer temperature and the short season.

## III. Soil Temperature and Moisture

**Observations of Soil Temperature.**—Readings were made by the authors at different times during the summer of 1908. The various plant formations were studied separately in order to have data of physical factors in the different habitats (see under Zonation, part IV). An

Table III. Soil Temperatures in Degrees Fahrenheit at Depth of 3 dm. during the Summer of 1908

| Date | Sedge Zone | Shrub Zone | Engelmann Spruce Forest | Dasiphora Assn. | Arenaria Assn. | Water of Lake |
|---|---|---|---|---|---|---|
| June 11 | 34 | 38 | 40 | 50 | 52 | 62 |
| June 28 | 39 | 43 | 38 | 52 | 52 | 69 |
| July 20 | 52 | 48 | 43 | 54 | 62 | 68 |
| Aug. 10* | 54 | 51 | 54 | 50 | 70 | 59 |
| Aug. 21* | 52 | 47 | 46 | 50 | 51 | 60 |
| Sept. 7† | 56 | 54 | 54 | 60 | 64 | 58 |
| Average | 47.8 | 46.8 | 45.8 | 52.7 | 58.5 | 62.7 |

* The month of August was wet, with much cloudy weather, so that temperatures are not as high as would ordinarily be the case.

† Preceded by a week of unseasonably hot weather; temperatures evidently above normal for the time of year.

examination of the table shows, what might be expected, that the forest soil is the coldest and the soil of the shrub zone next coldest. In both these cases the soil is shaded. In the forest the readings were taken among large Engelmann spruces. No observations were made in the drier mixed forest of limber pine and lodgepole pine (*P. flexilis* and *P. murrayana*). Without doubt the drier soil of this often more open forest is warmer than that of the mesophytic spruce forest. The *Arenaria* association has the warmest soil and the *Dasiphora* association the next warmest. Here there is no shade. Very early in the spring these forest openings warm up and there is a development of vernal

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flora which is nearly absent in the other localities. Especially is the absence of spring flora to be noted in the sedge zone where the soil is cold even through the month of June. The high temperature of the lake is accounted for by the slight depth of water.

**Soil Moisture Observations.**—Samples were taken at a depth of about 3 dm. with a soil borer, put at once into tight cans and weighed the same afternoon or the following day. After this they were dried in an oven to constant weight. In the printed figures all fractions have been omitted for sake of clearness. An examination of the averages in Table IV shows that the plant formations may be arranged as follows in order of moisture content: (1) *sedge zone;* (2) *shrub zone;* (3) *Engelmann spruce forest;* (4) *Dasiphora association;* (5) *Arenaria association.* The last, together with the dry pine forest, is xerophytic; the first four formations here named are mesophytic.

No study of non-available moisture was made but this may be roughly estimated by comparison of work by other investigators. In a field study by Hedgcock[1] at Lincoln, Neb., in the summer of 1900 it was found that the non-available water in "hard loam" was from about 5 to 6 per cent. for xerophytic plants. Since the soil of the *Arenaria* associations is a hard loam and coarse sand or gravel mixture the percentage would be less; but it is evident that there is very little available water any time during the summer. It is also to be remembered that the very low soil temperature in all the formations restricts the activity of roots, making them less able to absorb water from the soil. A series of studies on soil moisture of mountain districts is planned for the summer of 1909.

## IV. Zonation[2]

**General Account.**—Redrock Lake was chosen for study because of the sharply marked zonation presented. A belt of sedges extends all the way around the lake followed by a belt of dwarf willows and birches, which, in turn, is surrounded by coniferous forest (see Figs. 1 and 7).

[1] Hedgcock, George G., "The Relation of the Water Content of the Soil to Certain Plants, Principally Mesophytes," *Studies in the Vegetation of the State*, II (Botanical Survey of Nebraska, VI), p. 74, 1902.

[2] A preliminary account of the zonation of mountain lakes was presented by the writers at the Chicago meeting of the American Association for the Advancement of Science and the abstract was printed in *Science*, n. s., Vol. XXVII, p. 208, 1908.

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Naturally this zonation depends on edaphic factors of soil texture, amount of humus and moisture content. Some of these points have been discussed in the account of Geology and of the Soil.

TABLE IV. PERCENTAGE OF SOIL MOISTURE IN SAMPLES TAKEN AT DEPTH OF 3 DM. DURING THE SUMMER OF 1908

| Date | Sedge Zone | Shrub Zone | Engelmann Spruce Forest | Dasiphora Assn. | Arenaria Assn. |
|---|---|---|---|---|---|
| June 11 | 64 | 30 | 12 | 8 | 7 |
| June 28 | 62 | 20 | 13 | 21 | 5 |
| July 20 | 87 | 51 | 30 | 13 | 8 |
| Aug. 10 | 46 | 36 | 34 | 28* | 8* |
| Sept. 7 | 52 | 9 | 15 | 9 | 1 |
| Average | 62.2 | 29.2 | 21.0 | 15.8 | 5.8 |

* Undoubtedly above normal for this time of year. August was unusually wet in 1908.

**Previous Lake Studies.**—The first zonation studies of lake shores made in America were by MacMillan.[1] He distinguished many types of shores on this lake showing various kinds of zonation. His "dry morassic attached shores" show a zonation comparable to what is found at Redrock Lake. Here he distinguishes four zones: (1) Scirpus zone; (2) Salix zone; (3) Betula zone; (4) Larix zone. Other students of shore vegetation in this country have contributed to a knowledge of the lakes of the eastern and central parts of the United States. Mention may be made of articles by Messrs. John H. Schaffner, Geo. F. Atkinson, S. M. Coulter, Harry N. Whitford, Howard S. Reed, Lewis H. Weld, Otto E. Jennings, LeRoy Harris Harvey. This is not the place to summarize these studies; the writings of these authors with others in America and Europe will be considered in detail in a later paper by the present writers after the publication by them of further studies on the lakes of the Rocky Mountains of Colorado. The only work on shore vegetation in Colorado is that by Professor Frederic E. Clements who has worked so energetically upon the plants of the Pike's Peak region. In his "alpine bog formation" and "alpine lake formation" he names various species characteristic of each formation[2] and in his recent

[1] MACMILLAN, CONWAY, "Observations on the Distribution of Plants along Shore at Lake of the Woods," *Minn. Bot. Studies*, Vol. I, pt. 2, pp. 949–1023, 1897.

[2] CLEMENTS, FREDERIC E., "Formation and Succession Herbaria," *Univ. of Nebraska Studies*, Vol. IV, pp. 352, 353, 1904.

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textbook,[1] he publishes a figure illustrating the zonation at the lower end of Lake Moraine in the Pike's Peak district. The present intensive study of Redrock Lake does not duplicate the work of any previous writers.

### List of Species Collected from the Different Zones

#### Plants of Lake Zone

*Sparganium angustifolium*
*Potamogeton alpinus*
*Zannichellia palustris*
*Batrachium flaccidum*
**Nymphaea polysepala*

#### Plants of Sedge Zone

*Agrostis tenuiculmis*
*Deschampsia caespitosa*
*Hierochloe odorata*
*Poa reflexa*
*Carex canescens*
*Carex saxatilis*
*Carex siccata*
**Carex utriculata*
*Carex varicifilis*
*Eleocharis tenuis*
*Juncus balticus*
*Listera nephrophylla*
*Polygonum viviparum*
**Caltha leptosepala*
*Ranunculus reptans*
**Sedum rhodanthum*
**Saxifraga hirculis*
*Potentilla propinqua*
*Viola bellidifolia*
**Dodecatheon pauciflorum*
*Anthopogon barbellatus*
*Chondrophylla americana*
*Dasystephana romanzovii*
*Amarella monantha*
*Pleurogyne fontana*
*Swertia palustris*
**Elephantella groenlandica*
*Pedicularis scopulorum*
*Achillaea lanulosa*
*Crepis perplexa*
*Taraxacum montanum*

* Abundant and conspicuous species.

#### Plants of Shrub Zone

*Equisetum arvense*
*Picea engelmanni* (a few scattered specimens)
*Phleum alpinum*
*Streptopus amplexifolius*
*Corallorrhiza ochroleuca*
**Salix bebbiana*
**Salix chlorophylla*
**Salix glaucops*
**Salix lutea*
**Betula glandulosa*
**Arenaria sajanensis*
*Atragene occidentalis*
**Caltha leptosepala*
*Epilobium alpinum*
*Conioselinum scopulorum*
*Heracleum lanatum*
*Moneses uniflora*
*Pyrola secunda*
*Anthopogon elegans*
*Dasystephana parryi*
*Polemonium pulcherrimum*
*Castilleja confusa*
*Castilleja sulphurea*
**Pedicularis racemosa*
*Pedicularis grayi*
*Pentstemon procerus*
*Veronica wormskjoldii*

* Abundant and conspicuous species.

[1] Clements, *Plant Physiology and Ecology*, p. 295, New York, 1907.

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PLANTS OF SHRUB ZONE—*Continued*

**Trollius albiflorus*
*Saxifraga arguta*
**Saxifraga nivalis*
*Dasiphora fruticosa*
*Fragaria glauca*
*Potentilla dissecta*
*Sibbaldia procumbens*
*Sieversia turbinata*
*Viola bellidifolia*
*Viola blanda*
*Chamaenerion angustifolium*
*Lonicera involucrata*
*Achillaea lanulosa*
*Antennaria parvifolia*
**Erigeron salsuginosus*
*Erigeron salsuginosus glacialis*
*Senecio triangularis*
*Solidago decumbens minuescens*
*Crepis glaucella*
*Crepis perplexa*
*Crepis petiolata*

* Abundant and conspicuous species.

PLANTS OF FOREST ZONE

*Selaginella densa*
*Selaginella underwoodii*
**Abies lasiocarpa*
**Picea engelmanni*
**Pinus flexilis*
**Pinus murrayana*
*Juniperus sibirica*
*Calamagrostis purpurescens*
*Festuca ovina*
*Poa wheeleri*
*Zygadenus elegans*
**Juncus mertensianus*
*Streptopus amplexifolius*
*Populus tremuloides*
*Blitum capitatum*
*Lewisia pygmaea*
**Arenaria fendleri*
*Cerastium occidentale*
*Aconitum columbianum*
*Anemone globosa*
**Pulsatilla hirsutissima*
*Arabis drummondii*
*Draba streptocarpa*
**Erysimum wheeleri*
**Sedum stenopetalum*
*Mitella stenopetala*
*Saxifraga austromontana*
*Saxifraga rhomboidea*
*Ribes parvulum*
*Fragaria glauca*
**Lupinus alpestris*
**Thermopsis arenosa*
*Trifolium dasyphyllum*
*Chamaenerion angustifolium*
*Arctostaphylos uva-ursi*
**Vaccinium oreophilum*
*Androsace diffusa*
*Amarella scopulorum*
*Dasystephana parryi*
*Frasera speciosa*
*Polemonium confertum*
*Eritrichium argenteum*
*Mertensia lateriflora*
*Oreocarya pulvinatia*
**Castilleja confusa*
*Castilleja rhexifolia*
*Pedicularis parryi*
*Pedicularis racemosa*
**Penstemon alpinus*
*Penstemon glaucus stenosepalus*
*Penstemon procerus*
*Veronica wormskjoldii*
*Sambucus microbotrys*
**Campanula petiolata*
**Achillaea lanulosa*
**Antennaria parvifolia*
**Arnica cordifolia*
*Erigeron compositus*
**Erigeron trifidus*
**Erigeron salsuginosus glacialis*

* Abundant and conspicuous species.

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PLANTS OF FOREST ZONE—*Continued*

| | |
|---|---|
| *Potentilla concinna* | *Chrysopsis foliosa* |
| *Potentilla dissecta* | *Machaeranthera varians* |
| *Rosa sayi* | *Senecio mutabilis* |
| *Sibbaldia procumbens* | *Senecio perplexa* |
| **Aragallus lamberti* | *Senecio purshianus* |
| *Aragallus multiceps* | *Solidago decumbens minuescens* |
| **Aragallus multiceps minor* | *Tetraneuris lanata* |
| **Astragalus sulphurescens* | *Crepis perplexa* |

* Abundant and conspicuous species.

LAKE ZONE

The designation "lake zone" is used for convenience to make it correspond with the names of the shore formations. With so few species present it seems not desirable to separate *floating*, *submersed* and *half-submersed* zones.

The water lilies (*Nymphaea polysepala*) are the most prominent of the water plants. They form dense growths, especially at the western part of the lake where there is a soft mud bottom. There are also large floating "islands" of the leaves scattered about through the lake. It is not until mid-June that the lily pads become conspicuous. By July 1 a number of the plants are in bloom. From that time until the middle of August flowers are to be found in some part of the lake. Water lilies undoubtedly play an important part in the ultimate filling up of such lakes as the one under discussion.

Bur reed (*Sparganium angustifolium*) forms in places a distinct zone in water about 5 dm. (1.5 feet) deep. The long narrow leaves float on the surface in a close formation. The writers noticed in some of Stapp's lakes about three miles (5 km.) north of Redrock Lake an uninterrupted zone of *Sparganium* between the water lilies and the sedges of the shore. Professor Clements has noticed in certain lakes of the Pike's Peak region a complete filling up with this plant. This condition is recorded for Michigan Lake by Shantz.[1]

The only submersed species recognized by the writers are *Potamogeton alpinus*, *Zannichellia palustris* and *Batrachium flaccidum*. It is interesting to note the absence from this lake of *Myriophyllum*, *Polygonum*

[1] SHANTZ, "Biological Study of the Lakes of the Pike's Peak Region," *Trans. Amer. Mic. Soc.*, Vol. XXV, p. 85, 1907.

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*amphibium* and other hydrophytes so abundant in lakes of lower altitude. Species of *Utricularia* sometimes occur in lakes of high altitude elsewhere but none have been seen by the writers in the sub-alpine and alpine districts of northern Colorado. In the foothill lakes Utricularias are abundant.

Half-submersed plants are generally absent from the lake except *Carex utriculata* which, in places, forms a prominent zone about one meter wide along shore. There are no species of *Scirpus* or other common half-submersed plants of lower altitudes.

### Sedge Zone

The zone of sedges really begins in shallow water. *Carex utriculata*, as just noted, sometimes extends into the water (see Fig. 9). About 10 meters (32 ft.) may be taken as the average width of the sedge zone but on the north shore for a distance it is almost absent (see Fig. 1) and the willows and birches come nearly to the edge of the lake. The sedges collected are six in number, five species of *Carex* and one of *Eleocharis*. The gentians, which are characteristic of the autumn aspect, occur chiefly in this zone with the sedges.

The soil is very wet at all times and hence may be called "physiologically cold" even though it warms up in late summer with the heating of the lake water. Here then it is natural that many alpine plants should be found;[1] in fact one-third of the species belong to the alpine and sub-alpine districts. In the shrub zone only one-sixth and in the forest only one-fourteenth of the species belong essentially to higher altitudes. A comparison of the vegetation with that of the "wet meadows" at high altitudes can be made by reference to a recent paper by Mr. W. S. Cooper,[2] who names the following species which are also represented at Redrock Lake: *Carex* spp., *Caltha leptosepala*, *Sedum rhodanthum*, *Sieversia turbinata*, *Elephantella groenlandica*, *Dasystephana romanzovii* (*Gentiana frigida*).

Straggling shrubs from the next zone are found as invaders among the sedges in some places. This invasion occurs in places where the

[1] See the table in account of floristics.

[2] Cooper, W. S., "Alpine Vegetation in the Vicinity of Long's Peak, Colorado," *Bot. Gaz.*, Vol. XLV, pp. 319–37, 1908.

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sedge zone is very wide. In the filling up of shallow lakes, the shrubs generally enter with the sedges, forming small clumps in the wet meadow thus developed. An excellent illustration of this fact is seen in the meadow just beyond the bounding moraine west of Redrock Lake.

### Shrub Zone

The shrubs are massed in a narrow zone averaging about two meters (6.5 ft. )wide. *Salix chlorophylla* is the commonest species. It grows chiefly in the wetter parts and together with *Betula glandulosa* is advancing into the sedge zone. The other three willows are scattered about in clumps, sometimes of a single species, sometimes variously grouped. The birch, which, as has been said, is found in the wettest soil, is also found in other parts of the zone.

Both willows and birches are true shrubs, in no place trees. The birches, especially, are low, seldom more than one meter tall. It is somewhat remarkable that even with the comparatively unfavorable temperature there should be such a dense growth of these shrubs. Often they form an almost impassable thicket (see Fig. 10). In places individual clumps of shrubs extend to the water's edge and on the southwest shore a considerable number of shrub islands are scattered through an area of sedges (Fig. 1). In addition to the shrubs a few Engelmann spruces occur as wind timber at the east shore of the lake and elsewhere there are individual trees of this species among the shrubs and even in the sedge zone.

A number of mosses are abundant around the bases of the shrubs. In nearly all places a distinct ledge has been built up by the mosses at the boundary of the zone, next to the sedges. Species of *Sphagnum* and *Polytrichum* are the most important of these building mosses.

Most of the herbaceous plants recorded for this zone are found in openings and not in the shade under the shrubs. Various tongue-like areas of grassland extend radially across the zone or through a part of its width. Sometimes these are distinctly like portions of the sedge zone while elsewhere they are dominated by grasses from the forest. In still other places, while grasses are abundant, there are scattered shrubs of *Dasiphora fruticosa*. On the whole, however, the shrub zone

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is compact, with a flora of its own, not made up merely of stragglers from without.

A total of 48 species is recorded in this zone. Of these, 68 per cent. range to both lower and higher regions, while equal numbers (16 per cent.) belong respectively to lower and higher altitudes (Table V).

### Forest Zone

It may be somewhat misleading to speak of the forest as forming a "zone." The forest is, in fact, the typical plant formation of the region. At Redrock Lake, as elsewhere at the same altitude in northern Colorado, the character of the forest depends much on slope and soil moisture. In the wetter places, especially with north exposure, Engelmann spruce forms almost a pure forest, with only some slight admixture of sub-alpine fir (*Abies lasiocarpa*). The driest moraines and ridges support only the limber pine (*Pinus flexilis*). Places with intermediate conditions have a mixture of trees, chiefly lodgepole (*Pinus murrayana*) and limber pine and a few spruces and firs.

To the south of Redrock Lake there is a steep glacial moraine, which because of its slope to the north is cool and moist. Here is a dense forest of Engelmann spruce. On the north the trees are chiefly limber pines and lodgepole, the land here sloping gently to the lake at the south. East of the lake where a full sweep of wind is possible direct from the continental divide there is some typical "wind timber" forming close, flat-topped masses of scrubby spruce and fir. These produce such a dense shade that no plants except *Polemonium* will grow below.

The herbaceous plants of the forest are naturally more numerous than those of the other zones on account of the varied edaphic conditions. Although the plants collected were all from within a hundred meters (320 ft.) of the lake they are from dry and wet areas, open places and shaded spots, soils containing humus and soil made of coarse, disintegrated granite. On the whole, however, the forest may be considered xerophytic except where there are pure stands of Engelmann spruce. The soil is dry and many of the plants exhibit the structures looked for in dry-country species. The following are distinctly xerophytic: *Aragallus* spp., *Lupinus*, *Astragalus*, *Antennaria*, *Sedum*,

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*Arenaria*. It is such xerophytic species that form the main part of the vegetation, although some of the species listed for the forest zone are mesophytes. These occur chiefly on north slopes where the soil is moist from melting snow far into June or early July.

As shown in Table V one-third of the species collected in the forest zone are plants which range to lower altitudes and only 7 per cent. are of alpine distribution. The forest then is invaded to a considerable extent by low-country plants but is not entered to any extent by the plants from higher levels. This is what might be expected from the fact that alpine plants are poor "fighters" and would be unable to compete with the species belonging naturally to the altitude of Redrock Lake. Such alpine plants as do occur are here found in open places where the soil is very dry. Here, in early spring, conditions quite like those of the dry alpine tundra exist and such plants as *Eritrichium*, *Lewisia* and *Arenaria* are able to flourish.

A better understanding of the forest will be reached if the different conditions there present are fully stated. It is to be remembered that the forest is the natural plant formation of the region around Redrock Lake. The trees grow to moderate size, some of the Engelmann spruces in favorable situations being 6 to 8 dm. (2 to 3 ft.) in diameter. The limber pines are seldom more than 5 dm. (1.5 ft.) and often much less. None of the trees are deep-rooted. The soil is very thin and rocks come to the surface in many places. Wind storms from time to time uproot some of the trees, leaving open spaces. When this occurs it may be many years before the gaps are filled with trees. If the bare place is in the drier part of the forest it is likely that it will become occupied with xerophytic plants, some of them from the alpine region, but others low-country species. On the other hand, if the open space in the forest is moist—a seepage area—it grows up to *Dasiphora* and sedges, grasses and gentians. These two types of forest openings are present to the east of Redrock Lake. A short account of these as well as of the differences in the forest itself may be given at this point.

**Arenaria Associations.**—This name may be applied to plants of dry openings where soil is stony and there is very little humus. The conifers are at sufficient distance so that there are no pine or spruce

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needles on the ground to form a non-conducting surface covering. The soil therefore becomes very warm and dry because of intense insolation (see Tables III and IV). Most characteristic of these situations are the early-flowering mat plants such as *Arenaria sajanensis* and *Eritrichium argenteum* which are true alpine species.[1] Plants which flower somewhat later are: *Aragallus multiceps minor*, *Pulsatilla hirsutissima*. The Selaginellas come to fruit in early summer or late spring. Summer bloomers are generally just the ordinary forest plants, such as would occur where there was little shade: *Senecio*, *Aragallus*, *Artemisia*, *Chrysopsis*, *Frasera*. There is no autumn flora, as the soil becomes too dry for plant growth at that season. It is seen that the spring flora is of alpine type while the summer flora has rather montane and foothill affinities.

**Dasiphora Associations.**—This name is given to the plants of moister forest openings near the lake. Excellent examples are seen to the northwest of Redrock Lake and also at the southeast. These areas are either entirely within the forest or else bounded by the forest on three sides. Soil moisture is found to be intermediate in amount between what obtains in the shrub zone and the moist forest. The dominant species is *Dasiphora fruticosa* which forms scattered clumps about a meter apart leaving ample unshaded space for herbaceous plants. These latter are a mixture of mesophytes and xerophytes. Spring-blooming plants are not conspicuous. In summer there are such dry-country species as *Antennaria*, *Sedum stenopetalum*, *Solidago* and *Lupinus* side by side with moisture-requiring forms: *Elephantella*, *Pentstemon glaucus stenosepalus*, *Castilleja sulphurea*, *Polygonum viviparum*. This mongrel population indicates, of course, that the association is not a stable one but in a transition stage. From studies made elsewhere by the authors it is known that this stage may lead directly to Engelmann spruce forest, or that there may be an intermediate stage of aspen grove (*Populus tremuloides*). The autumn flora of the Dasiphora association is characterized by two or more species of gentians often in considerable numbers.

[1] In early spring this association is of alpine type and may be correlated with the "dry meadow"—a very inappropriate name—of Cooper in the article previously cited.

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**Aspen Association.**—As noted in the previous paragraph a growth of aspens sometimes forms an intermediate stage in the development of coniferous forest, from sedge or grassland. Only one small grove of aspen is found at Redrock Lake, located near the shore at the northwest. Aspens generally occur in fine-grained soil with some accumulation of humus and do not develop in coarse gravel and disintegrated granite. They are followed, at this altitude, by moist forest of Engelmann spruce and sub-alpine fir.

**Dense Dry Forest.**—In those parts of the forest where the soil is dry because of its shallowness or south exposure there may be, nevertheless, a dense tree growth. As a rule *Pinus murrayana* and *Pinus flexilis* are the dominant species with only an occasional spruce or fir. On the forest floor, which is well covered by pine needles, the most common plant is *Vaccinium oreophilum;* while scattered specimens of *Polemonium confertum* and certain few inconspicuous herbs make up the sparse flora of shade plants able to exist in these conditions. A few mosses, chiefly *Funaria hygrometrica*, occur at the bases of trees. Numerous lichens are present on the boulders and, in early autumn, agarics and pore fungi may be found in small number.

**Open Dry Forest.**—As in the dense dry forest, *Pinus murrayana* and *Pinus flexilis* are the dominant species. Here, however, more xerophytic conditions prevail. *Vaccinium oreophilum*, so common a plant on the forest floor elsewhere, is absent. Dry-country plants are the rule. *Juniperus sibirica*, *Lupinus alpestris*, *Aragallus lamberti*, *Sedum stenopetalum*, *Pentstemon alpinum* may be named as examples. There are no mesophytes. There is practically neither spring nor autumn flora since in spring there is too much shade for alpine plants and in the autumn the soil is too dry for the growth of even xerophytic foothill species.

**Moist Forest.**—This is commonly a close formation of Engelmann spruce with scattered individual pines and firs. A dense cover of spruce needles forms a mulch on the forest floor making it difficult for seedlings to become established. This condition, together with the dense shade, greatly limits the number of species. As in the case of the dense dry forest, *Vaccinium oreophilum* is the prominent plant of the forest floor.

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Secondary species of the floor are for the most part such as grow also in the shrub zone around the lake. Examples of these are *Lonicera involucrata, Ribes parvulum, Pyrola secunda, Moneses uniflora, Pedicularis racemosa.*

## V. Seasonal Aspects

**General Account.**—As shown in the account of climatology, the growing season is short. In 1908 freezing temperatures were recorded every week of June and as late as July 7. The first autumn frost came September 1. It is evident that spring-blooming plants must be few. They can be only alpine species or such forms as enter into the formation of the pre-vernal flora at lower altitudes.

**The Seasonal Limits.**—As a convenient classification spring may be said to begin about May 15 and extend to July 1; summer, July 1 to August 15; autumn, August 15 to October 1. Naturally such a division into seasons will seem somewhat unusual when, in most climates of the north temperate world, three months, June, July and August, are reckoned as forming the summer. The very short period of warm weather, however, makes the seasons only about six weeks in length. The special characters of each season[1] will be more fully set forth in the following paragraphs.

**Spring Aspect.**—Early in the season the soil of the sedge zone is cold. Because of its excessive moisture even the soil surface does not easily become warm. So there is little fresh vegetation in the early part of the season. In fact the sedge zone is brown with the dead plants of last year until late in June. Among the plants of the shrub zone the flowers of the willows and birches come out about June and the leaves are full grown a few weeks later. In the forest zone the soil is quickly warmed at the surface by the direct heat of the sun permitting the early growth and blooming of a certain number of species. These occur, for the most part, in open places where there is free access of sunlight. As

[1] A useful account of seasonal aspects in the mountain regions near Pike's Peak is given by Professor Frederic E. Clements in his "Formation and Succession Herbaria" (*Univ. of Neb. Studies*, Vol. IV, pp. 329–55, October, 1904) where he lists the species of each aspect. On page 346 is a list of the species in the "meadow thicket formation" of the sub-alpine zone, corresponding to our "shrub zone" at Redrock Lake. The aspects are much the same in these two parts of Colorado. In alpine districts he recognized only two periods, early and late; spring, summer and autumn not being distinguished.

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noted above spring begins about May 15. At this time there appear a few plants such as *Trollius*, *Caltha*, *Erysimum*, *Arenaria* and *Eritrichium*. Most of these continue to blossom well into the summer season also.

SPRING ASPECT: MAY 15 TO JULY 1. LIST OF PROMINENT SPECIES

| | |
|---|---|
| PLANTS OF THE SEDGE ZONE | |
| *Caltha leptosepala* | *Trollius albiflorus* |
| PLANTS OF THE SHRUB ZONE | |
| *Salix chlorophylla* | *Betula glandulosa* |
| *Salix bebbiana* | *Viola bellidifolia* |
| *Salix glaucops* | *Viola blanda* |
| *Salix lutea* | |
| PLANTS OF THE FOREST ZONE | |
| *Picea engelmanni* | *Eritrichium argenteum* |
| *Pinus flexilis* | *Arenaria sajanensis* |
| *Pinus murrayana* | *Aragallus multiceps minor* |
| *Abies lasiocarpa* | *Erysimum wheeleri* |

**Summer Aspect.**—The summer lasts from July 1 to August 15 and is characterized by the blooming of the water lilies (*Nymphaea polysepala*).

SUMMER ASPECT: JULY 1 TO AUGUST 15. LIST OF PROMINENT SPECIES

| | |
|---|---|
| PLANTS OF LAKE ZONE | |
| *Sparganium angustifolium* | *Nymphaea polysepala* |
| PLANTS OF THE SEDGE ZONE | |
| *Carex* spp. | *Caltha leptosepala* |
| *Sedum rhodanthum* | *Dasiphora fruticosa* |
| *Dodecatheon pauciflorum* | *Elephantella groenlandica* |
| *Poa reflexa* | |
| PLANTS OF THE SHRUB ZONE | |
| *Salix* spp. (fruit) | *Erigeron salsuginosus glacialis* |
| *Betula glandulosa* (fruit) | *Caltha leptosepala* |
| *Pedicularis racemosa* | |
| PLANTS OF THE FOREST ZONE | |
| *Picea engelmanni* (young cones) | *Vaccinium oreophilum* |
| *Pinus murrayana* (young cones) | *Campanula petiolata* |
| *Pinus flexilis* (young cones) | *Sedum stenopetalum* |
| *Abies lasiocarpa* (young cones) | *Thermopsis arenosa* |

**Autumn Aspect.**—The autumn aspect is characterized by the gentians. By this time the water lilies are through blooming and the fruit is developing, seldom becoming ripe until September 1 or later.

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AUTUMN ASPECT: AUGUST 15 TO OCTOBER 1. LIST OF PROMINENT SPECIES

PLANTS OF LAKE ZONE

*Sparganium angustifolium* (fruit)
*Nymphaea polysepala* (fruit)

PLANTS OF SEDGE ZONE

*Carex* spp. (fruit)
*Amarella monantha*
*Dasystephana romanzovii*
*Chondrophylla americana*
*Pleurogyne fontana*

PLANTS OF SHRUB ZONE

*Salix* spp.
*Anthopogon elegans*
*Betula glandulosa* (fruit)
*Dasystephana parryi*

PLANTS OF FOREST ZONE

*Picea engelmanni* (fruit)
*Abies lasiocarpa* (fruit)
*Pinus murrayana* (fruit)
*Amarella scopulorum* (Dasiphora society)
*Pinus flexilis* (fruit)
*Dasystephana parryi* (Dasiphora society)

## VI. FLORISTICS AND DISTRIBUTION

**General Account.**—The knowledge of the flora of Redrock Lake has been gained by collections and observations extending through two growing seasons. The experience of the writers in the present study has shown the inadequacy of collections and observations made for ecological purposes during one growing season only, even in such a restricted area as Redrock Lake. Not only does the field worker fail to see all the first time over the area, but the differences in the meteorological conditions from year to year influence the details in the vegetation and it is only by several seasons' observations that completeness is reached.

For convenience, and for purposes of comparison and reference, the species collected by the writers are listed both systematically and by zones.

The tables and discussions of distribution are intended to give to some extent the wider relations of the flora of Redrock Lake. The herbarium specimens have been arranged by zones, a different colored label being used for each zone.

The altitude and the flora of the area studied place it at about the lower limit of the sub-alpine zone[1] as recognized by the writers. From a consideration of the plants present, it seems to be in the middle of

[1] RAMALEY, FRANCIS, "Plant Zones in the Rocky Mountains of Colorado," *Science*, n. s., Vol. XXVI, pp 642, 643, 1907.

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the "Hudsonian" of Merriam[1] although the "average temperature for the six hottest weeks of summer" would place it at the top of the "Hudsonian" or bottom of the "Arctic." The altitude of Redrock Lake, 10,000 feet (3,080 meters), seems to correspond nearly to 8,500 feet (2,600 meters) on Mt. Shasta, California.[2]

SYSTEMATIC LIST BY FAMILIES

Equisetaceae
*Equisetum arvense* L.
Selaginellaceae
*Selaginella densa* Rydb.
*Selaginella underwoodii* Hieron.
Pinaceae
*Abies lasiocarpa* (Hook.) Nutt.
*Picea engelmanni* (Parry) Engelm.
*Pinus flexilis* James
*Pinus murrayana* "Oreg. Com."
Juniperaceae
*Juniperus sibirica* Burgsd.
Sparganiaceae
*Sparganium angustifolium* Michx.
Zanichelliaceae
*Potamogeton alpinus* Balbis
*Zannichellia palustris* L.
Gramineae
*Agrostis tenuiculmis* Nash.
*Calamagrostis purpurescens* R. Br.
*Deschampsia caespitosa* (L.) Beauv.
*Festuca ovina* L.
*Hierochloe odorata* L.
*Phleum alpinum* L.
*Poa reflexa* V. & S.
*Poa wheeleri* Vasey
Cyperaceae
*Carex canescens* L.
*Carex saxatilis* L.
*Carex siccata* Dewey
*Carex utriculata* Boott.
*Carex vaginifilis* Bailey
*Eleocharis tenuis* (Willd.) Schult.
Melanthaceae
*Zygadenus elegans* Pursh.
Juncaceae
*Juncus balticus* Willd.
*Juncus mertensianus* Bong.
Convallariaceae
*Streptopus amplexifolius* (L.) DC.
Orchidaceae
*Corallorrhiza ocheoleuca* Rydb.
*Listera nephrophylla* Rydb.
Salicaceae
*Populus tremuloides* Michx.
*Salix bebbiana* Sarg.
*Salix chlorophylla* Anders.
*Salix glaucops* Anders.
*Salix lutea* Nutt.
Betulaceae
*Betula glandulosa* Michx.
Polygonaceae
*Polygonum viviparum* L.
Chenopodiaceae
*Blitum capitatum* L.
Portulacaceae
*Lewisia pygmaea* (Gray) Robins.
Caryophyllaceae
*Cerastium occidentale* Greene
*Arenaria fendleri* A. Gray
*Arenaria sajanensis* Willd.
Ranunculaceae
*Aconitum columbianum* Nutt.
*Anemone globosa* Nutt.
*Atragene occidentalis* Hornem.
*Batrachium flaccidum* (Pers.) Rupr.
*Caltha leptosepala* Hook.
*Pulsatilla hirsutissima* (Pursh) Britton
*Ranunculus reptans* L.
*Trollius albiflorus* (A. Gray) Rydb.

[1] MERRIAM, "Life Zones and Crop Zones," *Bull. Biol. Surv.*, No. 10, p. 54, 1898.

[2] MERRIAM, *Biol. Surv. of Mt. Shasta, California* (N. A. Fauna No. 16), p. 52, 1899.

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SYSTEMATIC LIST BY FAMILIES—*Continued*

Nymphaeaceae
*Nymphaea polysepala* (Engelm.) Greene
Cruciferae
*Arabis drummondii* Gray
*Draba streptocarpa* A. Gray
*Erysimum wheeleri* S. Wats.
Crassulaceae
*Sedum rhodanthum* A. Gray
(*Clementsia rhodantha* (A. Gray) Rose)
*Sedum stenopetalum* Pursh.
Saxifragaceae
*Mitella stenopetala* Piper
*Saxifraga arguta* Don.
(*Micranthes* Small)
*Saxifraga austromontana* Wieg.
(*Leptasea* Small)
*Saxifraga nivalis* L.
*Saxifraga hirculis* L.
(*Leptasea* Small)
*Saxifraga rhomboidea* Greene
(*Micranthes* Small)
Grossulariaceae
*Ribes parvulum* (A. Gray) Rydb.
Rosaceae
*Dasiphora fruticosa* (L.) Rydb.
(*Potentilla fruticosa* L.)
*Fragaria glauca* (S. Wats.) Rydb.
*Potentilla concinna* Richardson
*Potentilla dissecta* Pursh.
*Potentilla propinqua* Rydb.
*Rosa sayi* Schweinitz
*Sibbaldia procumbens* L.
*Sieversia turbinata* (Rydb.) Greene
Papilionaceae
*Aragallus lamberti*
*Aragallus multiceps* (Nutt.) Heller
*Aragallus multiceps minor* (A. Gray) Rydb.
*Astragalus sulphurescens* Rydb.
*Lupinus alpestris* A. Nels.
*Thermopsis arenosa* A. Nels.
*Trifolium dasyphyllum* Torr.
Violaceae
*Viola bellidifolia* Greene
*Viola blanda* Willd.
Epilobiaceae
*Chamaenerion angustifolium* (L.) Scop.
*Epilobium alpinum* L.
Umbelliferae
*Conioselinum scopulorum* (A. Gray) C. & R.
*Heracleum lanatum* Michx.
Pyrolaceae
*Moneses uniflora* (L.) S. F. Gray
*Pyrola secunda* L.
Ericaceae
*Arctostaphylos uva-ursi* (L.) Spreng
Vacciniaceae
*Vaccinium oreophilum* Rydb.
Primulaceae
*Androsace diffusa* Small
*Dodecatheon pauciflorum* (Durand) Small
Gentianaceae
*Amarella scopulorum* Greene
(*Gentianella clementis* Rydb.)
*Anthopogon barbellatus* (Engelm.) Rydb.
(*Gentiana* Engelm.)
*Anthopogon elegans* (A. Nels.) Rydb.
(*Gentiana* A. Nels.)
*Chondrophylla americana* (Engelm.) A. Nels.
(*Gentiana prostrata* Hook; var. *americana* Engelm.)
*Dasystephana parryi* (Engelm.) Rydb.
(*Gentiana* Engelm.)
*Dasystephana romanzovii* (Ledb.) Rydb.
(*Gentiana* Ledb.)
*Frasera speciosa* Dougl.
*Amarella monantha* (A. Nels.) Rydb.
(*Gentiana* A. Nels.)
*Pleurogyne fontana* A. Nels.
*Swertia palustris* A. Nels.
Polemoniaceae
*Polemonium confertum* A. Gray
*Polemonium pulcherrimum* Hook.
Boraginaceae
*Eritrichium argenteum* Wight

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SYSTEMATIC LIST BY FAMILIES—*Continued*

*Mertensia lateriflora* Greene
*Oreocarya pulvinata* A. Nels.

Scrophulariaceae
*Castilleja confusa* Greene
*Castilleja rhexifolia* Rydb.
*Castilleja sulphurea* Rydb.
*Elephantella groenlandica* (Retz.) Rydb.
*Pedicularis grayi* A. Nels.
*Pedicularis parryi* A. Gray
*Pedicularis racemosa* Dougl.
*Pedicularis scopulorum* A. Gray.
*Pentstemon alpinus* Torr.
*Pentstemon glaucus stenosepalus* A. Gray
*Pentstemon procerus* Dougl.
*Veronica wormskjoldii* R. & S.

Caprifoliaceae
*Lonicera involucrata* Banks
*Sambucus microbotrys* Rydb.

Campanulaceae
*Campanula petiolata* DC.

Compositae
*Achillaea lanulosa* Nutt.

Compositae
*Antennaria parvifolia* Greene
*Arnica cordifolia* Hook.
*Erigeron compositus* Pursh.
*Erigeron salsuginosus* (Richardson) A. Gray
*Erigeron salsuginosus glacialis* (Nutt.) A. Gray
*Erigeron trifidus* Hook.
*Chrysopsis foliosa* Nutt.
*Machaeranthera varians* Greene
*Senecio mutabilis* Greene
*Senecio perplexa* A. Nels.
*Senecio purshianus* Nutt.
*Senecio triangularis* Hook.
*Solidago decumbens minuescens* A. Nels.
*Tetraneuris lanata* (Nutt.) Greene

Cichoriaceae
*Crepis glaucella* Rydb.
*Crepis perplexa* Rydb.
*Crepis petiolata* Rydb.
*Taraxacum montanum* Nutt.

It will be noted from the systematic list that the families represented by a considerable number of species are: Gramineae, 8 species; Cyperaceae, 6 species; Salicaceae, 5 species; Ranunculaceae, 8 species; Saxifragaceae, 6 species; Rosaceae, 8 species; Papilionaceae, 7 species; Gentianaceae, 10 species; Scrophulariaceae, 12 species; Compositae (excluding Chicoraceae), 15 species. The Polypodiaceae, Liliaceae and Labiatae, although distributed in Colorado all the way from the plains to alpine regions, are not represented in the Redrock Lake flora. The Solanaceae and Euphorbiaceae, so common and conspicuous in the plains and foothills, do not ascend to the altitude of Redrock Lake.

## ALTITUDINAL RANGE OF SPECIES[1]

It is worth noting that while a larger number of the species of the sedge zone range up, the species of the forest zone for the most part range down. This relation is evidently due to the difference in the

[1] For an exhaustive discussion of the altitudinal distribution of Colorado alpine plants as revealed by the statistics and locality records in RYDBERG'S *Flora* the reader is referred to the "Alpine Flora of Colorado' by Professor T. D A. COCKERELL in *The American Naturalist*, Vol. XL, pp. 861–73, 1906.

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amount of precipitation and general moisture conditions which prevail in high and low altitudes. Of the entire flora of Redrock Lake, a greater proportion of the species range down than range up. A list of

TABLE V

PERCENTAGE OF THE SPECIES OF EACH ZONE BELONGING TO DIFFERENT ALTITUDES

| Zone | Ranging Both Up and Down* | Ranging Up† | Ranging Down‡ |
|---|---|---|---|
| | Per cent. | Per cent. | Per cent. |
| Lake | 60 | 0 | 40 |
| Sedge | 44 | 33 | 23 |
| Shrub | 68 | 16 | 16 |
| Forest | 60 | 7 | 33 |
| Entire flora | 62 | 11 | 27 |

* For the most part montane and sub-alpine plants.
† For the most part alpine and sub-alpine plants.
‡ For the most part montane and foothill plants with some from the plains region.

the species which have the altitude of Redrock Lake either as their upper or lower limit of distribution is as follows:

HIGH-ALTITUDE PLANTS WHICH SELDOM EXTEND IN COLORADO TO ALTITUDES LOWER THAN THAT OF REDROCK LAKE

SEDGE ZONE

*Agrostis tenuiculmis*
*Sedum rhodanthum*
*Chondrophylla americana*
*Dasystephana romanzovii*
*Pedicularis scopulorum*

SHRUB ZONE

*Arenaria sajanensis*
*Sibbaldia procumbens*
*Sieversia turbinata*

FOREST ZONE

*Eritrichium argenteum*
*Solidago decumbens minuescens*

LOWER-ALTITUDE PLANTS WHICH SELDOM EXTEND IN COLORADO TO ALTITUDES HIGHER THAN THAT OF REDROCK LAKE

LAKE ZONE

*Batrachium flaccidum*

SEDGE ZONE

*Carex siccata*
*Carex utriculata*
*Ranunculus reptans*
*Crepis perplexa*
*Crepis petiolata*
*Taraxacum montanum*

SHRUB ZONE

*Equisetum arvense*
*Salix bebbiana*
*Streptopus amplexifolius*
*Atragene occidentalis*
*Dasiphora fruticosa*
*Castilleja sulphurea*

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LOWER-ALTITUDE PLANTS—*Continued*

FOREST ZONE

| | |
|---|---|
| *Selaginella densa* | *Viola blanda* |
| *Selaginella underwoodii* | *Chamaenerion angustifolium* |
| *Blitum capitatum* | *Heracleum lanatum* |
| *Potentilla concinna* | *Mitella stenopetala* |
| *Rosa sayi* | *Penistemon alpinus* |
| *Aragallus multiceps* | *Erigeron compositus* |
| *Astragalus sulphurescens* | *Senecio mutabilis* |
| *Thermopsis arenosa* | *Crepis perplexa* |

EXTENSIONS OF ALTITUDINAL RANGE

The following list gives an extension of the altitudinal range of species given by Rydberg in his *Flora of Colorado*. The range as stated by Rydberg is placed in parentheses. Only two of these are downward extensions. The others are all species hitherto reported only from lower altitudes.

| | |
|---|---|
| *Selaginella densa* | up to 10,100 ft. (7,000)[1] |
| *Selaginella underwoodii* | 5.000–10,100 ft. (7,500) |
| *Zannichellia palustris* | 4,000–10,100 ft. (9,000) |
| *Hierochloe odorata* | 6,500–10,100 ft. (8,500) |
| *Atragene occidentalis* | 5,000–10,100 ft. (7,000) |
| *Dasystephana romanzovii* | (11,000) 10,100–14,000 ft. |
| *Dodecatheon pauciflorum* | up to 10,100 ft. (8,500) |
| *Eritrichium argenteum* | (11,000) 10,100–14,400 ft. |
| *Lonicera involucrata* | 7,000–10,100 ft. (9,000) |
| *Erigeron compositus* | 8,000–10,100 ft. (9,000) |
| *Machaeranthera varians* | 6,000–10,100 ft. (8,000) |
| *Senecio mutabilis* | 5,000–10,100 ft. (9,000) |
| *Crepis glaucella* | up to 10,100 ft. (7,500) |
| *Crepis perplexa* | 5,000–10,100 ft. (9,000) |
| *Crepis petiolata* | 7,000–10,100 ft. (9,000) |
| *Taraxacum monatum* | up to 10,100 ft. (9,500) |

From Table VI, computations in percentages show that while 100 per cent. of the families and 91 per cent. of the genera represented at Redrock Lake are common to North America, Europe and Asia, 70 per cent. of the species are found in North America only and 60 per cent. of the species are found exclusively in western North America.

[1] COOPER, WILLIAM S., "Alpine Vegetation in the Vicinity of Long's Peak, Colorado," *Bot. Gaz.*, Vol. XLV, pp. 319–37, May, 1908, reports this species from alpine regions.

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It is often remarked that the flora of the western United States is much like that in the eastern United States. However, only 27 per cent. of

TABLE VI

GEOGRAPHICAL RANGE OF FAMILIES, GENERA AND SPECIES

| | Families | Genera | Species |
|---|---|---|---|
| Number represented at Redrock Lake | 41 | 100 | 140 |
| Common to North America, Europe and Asia | 41 | 91 | 39 |
| North America and Asia, not Europe | 0 | 4* | 4 |
| North America and Europe, not Asia | 0 | 0 | 0 |
| North America only | 0 | 5† | 97 |
| Both East and West North America, not Europe or Asia | 0 | 4 | 13 |
| West North America exclusively | 0 | 1‡ | 84 |

* *Castilleja, Mitella, Penstemon, Zygadenus.*
† *Dodecatheon, Chrysopsis, Frasera, Lewisia, Tetraneuris.*
‡ *Lewisia.*

the species at Redrock Lake occur also in the eastern United States. Thus it is seen that the flora of Redrock Lake is decidedly western.

## VII. SUMMARY

For purposes of reference it may be well to summarize briefly the scope of the foregoing paper. It is an ecological study of a morainal lake (Redrock Lake) in the Rocky Mountains of northern Colorado. The lake has an altitude of 10,100 feet (3,080 meters). The vegetation is of the sub-alpine type. The present work is the first attempt to make an intensive ecological study of a Rocky Mountain lake. The contents of the paper can be ascertained from the section headings which are as follows: I, Topography and Geology; II, Climatology; III, Soil Temperature and Moisture; IV, Zonation; V, Seasonal Aspects; VI, Floristics and Distribution.

A consideration of the past geological history, of the present topography and geology, as well as of the various climatological and habitat factors, are discussed in their relation to the present condition and composition of the flora of the lake. The arrangement of the zones about the lake, their composition and relationships are indicated. The following zones are recognized: (1) Lake zone, characterized by *Nymphaea polysepala;* (2) Sedge zone, consisting for the most part of five

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species of *Carex* and one of *Eleocharis;* (3) Shrub zone, a Salix-Betula formation; (4) Forest zone, the principal formation of the area, consisting of a dense dry forest of *Pinus murrayana* and *Pinus flexilis* and a moist forest of *Picea engelmanni.* Engelmann spruce forest is the characteristic formation of the sub-alpine region.

The growing season is short, extending from May 15 to October 1. The seasonal limits are as follows: Spring, May 15 to July 1; summer, July 1 to August 15; autumn, August 15 to October 1. The spring aspect is characterized by the blooming of plants in the drier parts of the forest zone and by the complete absence of fresh vegetation in the sedge zone. The summer is marked off by the blooming of water lilies and the appearance of a rich herbaceous flora in all the zones. In the autumn a few late-blooming species appear, chiefly of the gentian family.

The flora of Redrock Lake consists of 140 species, in 100 genera and 41 families. The following families are well represented: Gramineae, 8 species; Cyperaceae, 6 species; Salicaceae, 5 species; Ranunculaceae, 8 species; Saxifragaceae, 6 species; Rosaceae, 8 species; Papilionaceae, 7 species; Gentianaceae, 10 species; Scrophulariaceae, 12 species; Compositae, 15 species. The extension of the altitudinal distribution of 15 species is noted. A table giving the geographical range of the families, genera and species shows the wider relations of the Redrock Lake flora.

Future papers by the writers will discuss the ecology of about 25 lakes occurring at various altitudes in the Rocky Mountain region. These lakes are of various geologic types and are in different ecological stages. Comparisons of these lakes with one another and with those studied by other botanists will be made.

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FIG. 7.—View of plant zones. Scattered lily pads are shown in the water; sedges at the lake edge; then birches and willows of the shrub zone; finally Engelmann spruces of the forest zone. Photograph by Mr. G. S. Dodds.

REDROCK LAKE NEAR WARD, COLORADO

(I)

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FIG. 8.—Marginal rim. The sedge zone here is very narrow, the dwarf birches and willows, not as tall as a man, coming close to the water's edge. The picture was taken in June before the leaves had come out on the shrubs. Photograph by Mr. G. S. Dodds.

FIG. 9.—Sedge zone along the south shore. The invasion of the lake by sedges is shown. Photograph by Mr. G. S. Dodds.

REDROCK LAKE NEAR WARD, COLORADO

(II)

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FIG. 10.—"Wind timber" on the east shore. The birches and willows here form a thick, matted growth upon which it is even possible to walk. The prevailing direction of the wind is seen to be from the west, as is evidenced by the absence of projecting branches on the west side of the two large Engelmann spruces. Photograph by Mr. G. S. Dodds.

FIG. 11.—Large snowdrift on the moraine east of the lake, June 6, 1908. Small drifts remain about the lake until July 1. *Sibbaldia procumbens* grows in the loose soil kept moist by the melting of the snow. This ridge is exposed and would be dry if it were not for the snow which collects there every year. Photograph by Mr. G. S. Dodds.



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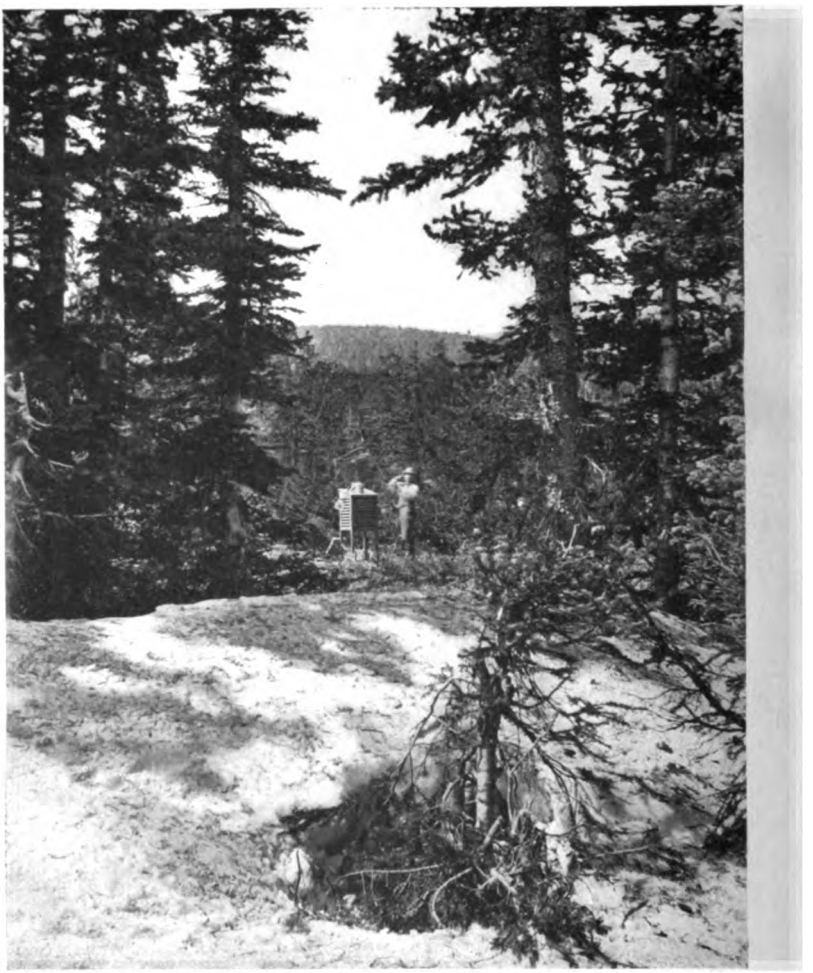

FIG. 12.—Instrument shelter in which thermograph was kept, in opening of Engelmann spruce forest, June 6, 1908. The snowdrift in the foreground is covered with scattered spruce twigs and needles. Photograph by Mr. G. S. Dodds.

REDROCK LAKE NEAR WARD, COLORADO

(IV)

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# CONTENTS

PAGE

1. THÉODORE TRONCHIN: A FASHIONABLE FRENCH PHYSICIAN OF THE EIGHTEENTH CENTURY . . . . . 173
CARROLL E. EDSON, A.M., M.D.
Professor of the Theory and Practice of Medicine

2. THE FENIAN MOVEMENT . . . . . 187
CLYDE L. KING, M.A.
Acting Professor of Economics and Sociology

3. THE ELECTROCHEMISTRY OF THE SOLUTION OF GOLD IN POTASSIUM CYANIDE . . . . . 215
JOHN B. EKELEY, PH.D.
Professor of Chemistry
and
ARTHUR L. TATUM, M.S.
Instructor in Chemistry

4. AN ANNOTATED LIST OF THE BIRDS OF BOULDER COUNTY, COLORADO . . . . . 219
JUNIUS HENDERSON, B.A.
Curator of the Museum

5. THE BEMBECID WASPS OF BOULDER COUNTY, COLORADO . . 243
SIEVERT A. ROHWER

6. THE SILVA OF COLORADO. IV. FOREST FORMATIONS AND FOREST TREES . . . . . 249
FRANCIS RAMALEY, PH.D.
Professor of Biology

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# THÉODORE TRONCHIN:[1] A FASHIONABLE FRENCH PHYSICIAN OF THE EIGHTEENTH CENTURY

By Carroll E. Edson

When the great Boerhaave was on his deathbed he said to a friend and former favorite pupil who, weeping, expressed the hope that he would yet be spared, "You must not forget, dear friend, that opinion rules the world. When Sylvius de la Boë died, his loss was thought irreparable: two years later he was already forgotten: it will be the same with me, and it must be so."

Boerhaave is to most of us only a name. The friend to whom he spoke and who became his successor in European fame, who enjoyed a *clientèle* as great as, if not greater than his master's, is almost unknown. Yet he was a giant in his day, and wrought mightily.

Théodore Tronchin was born in Geneva on May 24, 1709, the son of a banker, descended from a Protestant family of Provence, which had sought asylum in the freedom of Switzerland. He received a liberal education in the college and academy of his native city, and was studying theology when the collapse of Law's gigantic bubble brought financial ruin on his father. The lad was thereupon sent to England to the protection of Lord Bolingbroke, a distant relative by marriage. For several years he enjoyed the advantage of the brilliant society at Dawley, where Pope and Swift made with Bolingbroke the triad of an intellectual and worldly galaxy.

Deciding upon the study of medicine, he went to Cambridge, to which university the foundation of Caius and Gonville College long attracted the medical scholarship of England. While here he read Boerhaave's treatise on chemistry, which so captivated him that he determined forthwith to go to Leyden to study under the great teacher. On his way he tarried for a while in London, where he met Mead, the

[1] *Théodore Tronchin* (1709-81) *d'après des documents inédits;* par Henry Tronchin. Paris: Librairie Plon, 1906.



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leading English physician of his time, a man of great culture—the first collector of medical portraits. From him the young student received a bit of advice which doubtless had its effect on his later work, for all his practice showed a close obedience to his teaching. "I have done little good," said Mead, "but have been most careful never to do any harm."

In September, 1728, Tronchin enrolled himself as a student of medicine in Leyden, at that time perhaps the most famous medical center in Europe. Albinus was teaching anatomy, and Boerhaave held the chair of medicine, chemistry, and botany. Such was the zeal and industry of Tronchin that in less than two years he received his doctor's hood.

Early in his course he had attracted the attention of Boerhaave by his enthusiasm and the quickness with which he acted on a hint.

Remarkably handsome as a youth, Tronchin was not a little of an exquisite. Boerhaave remarked one day that the elegance of his hair, dressed according to the elaborate fashion of the day, must take a great deal of time. This comment being told to Tronchin he at once had his hair clipped short and won the deepened interest of his master, whose favorite pupil he soon became.

Settling in Amsterdam he rapidly became noted for his skill. A graciousness of manner won him a *clientèle* which his professional ability enabled him to hold. Boerhaave was unstinted in his friendship and regard, and soon, when consulted by patients from Amsterdam, would say to them, "Go back home. You have in your own city another me."

Tronchin's early success in Amsterdam was helped by his skill in management of a very severe and fatal epidemic of colic—probably of lead-poisoning. His experience in this disease led later to his choice of subject for the only book he ever published.

The early discouragements which the young physician meets were, however, not unknown to Tronchin. The petty and obstructive jealousies of today were not unknown then. It is not unconsoling, therefore, to read in a letter of encouragement which Van Swieten, the professor of medicine at Leyden and later physician to Marie Theresa, sends to Tronchin: "It is the misfortune attaching to our profession

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that the charlatans are more esteemed than the wise of our art. Heed them not, though they look down upon the ablest with disdain."

So rapid was his success that by thirty he was well known in Europe, and was already president of the College of Physicians of Amsterdam. Boerhaave, as his health began to fail, tried hard to persuade his pupil to come to Leyden as his successor; but the disturbed political conditions in Holland, as well as the social and economic state brought about by the war of the Austrian Succession, determined him to return to Geneva. His graciousness and ease of manner covered an earnest, deeply religious character, trained in the Calvinistic theology, and he wished to educate his two sons, now lads in their early 'teens, in a cleaner social and moral atmosphere than that of the Netherlands, where, to use his words, "luxury increased as prosperity became less real . . . . where money standards ruled in everything, and there were no longer manners, morals, or religion."

In 1753, therefore, he moved to Geneva, though he was offered every inducement to remain in Holland. The regent offered him the position of physician to the Stadtholder, then aged five, and a pension of 15,000 florins, while the Empress of Russia invited him to Moscow upon his own terms to be her physician.

Upon his arrival in Geneva there took place a display of medical temper which throws an interesting light upon the workings of medical registration boards in those days. The Faculty of Medicine, as it was known in Geneva, was composed of doctors in medicine, surgeons, and apothecaries. It was governed by the president, the senior doctor in medicine, and two seigneurs commis, appointed by the Council of State. No one could practice any of the three professions in the republic without being elected to this Faculty or Corps of Medicine, and this election could be had for physicians only on presentation of a diploma from a recognized university, followed by an examination. Desiring to make a fellow-member of the illustrious pupil of Boerhaave the Faculty had obtained permission from the Council to dispense with the customary examination, and were preparing to elect Tronchin by acclamation when the little incident occurred which cut through to their human nature.

There had been founded in 1567, by Theodore Beze, a chair of medicine

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in the Academy or University of Geneva, which was shortly afterward suppressed by the Council because of lack of funds. The Academy had long wanted to re-establish their foundation, but had been blocked by the Faculty of Medicine, who, controlling the election of physicians, and supervising that of the surgeons and apothecaries, were jealous of any rival creation in the Academy.

On February 24, 1755, the Senate of the Academy proposed formally to the Council to re-establish the professorship of medicine in favor of Tronchin, adding as a clinching argument that "there would be no question of salary for a man who had voluntarily left such position and refused such advantageous offers." At the same session the Council acceded to the request of the Academy, and unanimously bestowed on Tronchin the title, rank, and honors of honorary professor of medicine. The corporation of the city, "The Worshipful Company," hastened to make Tronchin a member of the Assembly.

All this being done without the knowledge of the Faculty, they therefore declined to elect the new professor to the Corps of Medicine, and repeatedly postponed all actions necessary to securing him a place to lecture by voting every place proposed by Tronchin's supporters as "unfit for so great a man." It finally took the official action of the Council of State to bring the Faculty to terms.

When once established in Geneva, Tronchin's fame spread rapidly, and soon patients flocked to him from all over Europe. Two things, besides his skill, contributed to his reputation: his friendship with Voltaire, and his successful inoculation for smallpox of the children of the Duke of Orleans.

Voltaire took up his residence in Geneva the same year that Tronchin returned. He became the most devoted and enthusiastic admirer of his physician, though he followed his medical advice only when he chose, a trait not wholly unknown today. The nervous old hypochondriac was always meddling in local politics and getting himself into serious difficulties with the authorities, from which Tronchin, who was already in a position of influence, time and again extricated him by personal appeal to the government officials. Voltaire, who always had a serious illness ready for such occasions, secluded himself in his room till the

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storm blew over, and, being a voluminous correspondent, sounded the praises of his physician on all sides, spreading the name of Tronchin among the great of every country—"as wise as Esculapius, as he is handsome as Apollo." In one of his letters he writes "he understands the mind; he is a great physician." From Tronchin's letters of advice to his patient and from entries in his journal, we may be sure that the great physician did thoroughly understand the smallness of soul of the old rascal. Much as he appreciated the power of mind and keenness of wit of Voltaire, Tronchin's own deeply-rooted character forbade any deception as to the real shallowness of the philosopher's nature. The correspondence between the two men throws light upon a most interesting side of Voltaire's life, and explains the political origin of many of the philosopher's reputed illnesses.

The other factor in the spread of Tronchin's fame was his visit to Paris in 1756 to inoculate the Duc de Chartres. At this day it is difficult to realize the terrible and ever-present scourge of smallpox before the discovery of Jenner. Of every two children born one would some time die of the disease. A person whose face was unmarked by pits was the exception. Many of the famous beauties of the day, whose portraits do not to us confirm the excessive laudation of their admirers, owed not a little of their repute to the mere fact of a complexion unscarred by pits of smallpox. The constant dread of the disease was intensified from time to time by its increase from endemic to epidemic proportions. In Paris in the year 1723 not less than 23,000 persons died from this disease.

The introduction to Europe of the practice of inoculation against smallpox was due, as is well known, to Lady Wortley Montague, wife of the English ambassador to Constantinople, who in 1718 had her son so protected in the East, and in 1721 her other child, after returning home. In England the practice met with fairly ready acceptance, as it did in America, owing to the support of Cotton Mather and Dr. Zabdiel Boylston. On the continent the Low Countries adopted this method of protection. In 1748 Tronchin inoculated his oldest son, and so great became his skill in this procedure that he soon became noted as the ablest inoculator on the continent, and his advocacy did much to extend the practice in Holland and later in Switzerland. His success was due

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to his great care in the preliminary upbuilding of his patients' health, and the minute attention to all matters of hygiene during the illness. I can find no record of any fatal result under his care. Widespread as this new method became in England and other countries, in France it met with the greatest opposition and neglect. The clergy saw in it only defiance of the will of God, and set it down as "criminal, murderous, and tainted with magic," while the medical profession contemned the innovation with blind disdain. In spite of the efforts of La Coste, Chirac, and La Condamine, the cause of inoculation made no headway. Voltaire wrote "This method has had the same success here (Geneva) as in England. The turn of the French comes very late, but it will come."

In 1756 the Duke of Orleans determined to have his two children, the Duc de Chartres and Mlle. de Montpensier, inoculated, despite the opposition of the court, and was persuaded by Senac to call Tronchin to Paris, since his skill assured the success of the operation. (Grimm says that Senac did this to vent his spite against the Medical Faculty of Paris, with whom he was on unfriendly terms.) The operation was done on March 25, and for three weeks all Paris waited breathlessly for the result. Rumors of every kind were afloat; handbills and lampoons of the most venomous nature were circulated; but on April 10, the *Gazette* officially announced the successful issue of the case, whereupon, with the fickleness of courtly zeal, the utmost enthusiasm and laudation replaced the former vituperation. Tronchin became the idol of the day. Crowds blocked his carriage to get a sight of him. He was received in private by the King and Dauphin, and dined with the Queen at a state banquet. "Inoculation bonnets" became the fashion, with ribbons embroidered with yellow dots to represent the pustules of smallpox, while the street hawkers did a thriving trade in selling "Tronchin smelling-salts, a sure preventive against contagious diseases."

Loaded with rewards and honors, Tronchin returned to Geneva soon to be called to Italy, where he successfully inoculated the children of the Duke of Parma, for which he was made a noble citizen of Parma. His correspondence gives an interesting account of the ceremony, which

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seems in no way to have turned his head. From this time Tronchin became the best-known physician in Europe. Not only did people come to Geneva to be inoculated by him, but to consult him for every ailment. A voluminous correspondence shows the extent and quality of his *clientèle*; for in that day the lack of laboratory methods, and the diagnosis of disease by symptoms, enabled in greater degree than now the successful management of patients by correspondence. Not only the noblesse of France became his patients, but the Queen of Sweden, the King of Denmark, the Elector Palatine, the Princes Hohenzollern and Anhalt, the Duke of Savoy, and even Pope Clement XIV consulted him, rigid Calvinist though the doctor was, about the health of Cardinal Colonna.

In 1766 Louis Phillipe, Duc d'Orleans, who had remained a firm friend of the Genevan physician, invited him to Paris as his physician in place of the aged Petit who resigned by reason of illness. The duke writes "I assure you that I deserve your friendship, for I esteemed you before I knew you personally; but now I love you, and am under obligation to you for making safe the future of my son." After some hesitation Tronchin accepted the position and moved to Paris, where he was most comfortably lodged in the Palais Royal, in a suite of five apartments. A cook and three servants were assigned him, and he had the use of a coach and two pairs of beautiful black horses.

If he had thought his move would give him leisure for his remaining years, he was much mistaken. Aside from the constant attendance upon the duke, who led a most strenuous life of exercise and social activity, Tronchin was overwhelmed with attention and the burden of fashionable practice. His former patients welcomed his coming to Paris with enthusiasm, and hastened to show their joy. The duchess d'Arville sent a bust of Esculapius for his library—Mme. Jancourt a Turkish carpet.

The remaining fifteen years of his life were spent in the midst of the complex life of the French court, preceding the Revolution, and busied with the details of an increasing practice, which, fashionable as it was, remained loyal and undiminished to his death. This practice was so extensive and successful, not only among the rich but also among the

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poor, that it excited the jealousy of his fellow practitioners, a jealousy which was not made more friendly by his radical departure from established lines of treatment, and his freely expressed contempt for the therapeutic systems of the day. He writes in 1763 to de Boisgelin:

> Systems spoil everything, in medicine as in physics. In the one as in the other there is need of observation, reflexion, attention. This road is less pleasant and harder, but on it alone are we safe from error.

Elsewhere he writes:

> I have pondered my patients, not my books.

Fully to appreciate the meaning of this criticism and the reasons for the popularity of the new methods of practice which he instituted, it must be remembered that much stress was laid at that time upon the philosophic theories of disease based upon insufficient knowledge of facts; while the means of treatment adopted for all and every ailment were violent emetics and purgatives and repeated copious bleedings. For instance, in a letter he writes to the countess d'Arcussia, commenting on the treatment she had received:

> I recall, madame, that a patient from one of the foremost cities in France, who was much more ill than you, consulted me some six years ago about her eight hundred and thirty-third bleeding, which, although ordered by her physician, had failed to draw blood. . . . . She had been directed to return in a week, as "between now and then perhaps some blood will form."

It was for such harsh, ill-considered measures that Tronchin substituted the simple treatment which we should now call hygienic living. "Simplicity in medicine," he wrote, "is sure to follow when one watches nature. The number of specifics diminishes in proportion as wisdom grows."

It is a curious comment on the ways of the human intellect that this fight for rational observation and simple means of cure has been always a recurring necessity. The letters of Tronchin read almost to the word with the pleas made a century later by men like Dr. Holmes and Dr. Bigelow, and he himself said "Hippocrates was the originator of any system which I may have, namely, that of observation of nature, and obedience to the reasoning thence deduced."

Simplicity and temperance in diet, sufficient exercise, and abundant fresh air were the members of his professional trinity. Always and

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everywhere he insists on obedience to these precepts, the need of which in those days we can now hardly realize. Yet his directions are even today being preached as novelties.

The need of fresh air was especially urgent among the fashionable world of that time, when the bedrooms were often wholly unlighted and unventilated. The canopied and curtained feather-beds in which the luxurious spent many hours shut out every chance of air, and even in palaces like Versailles the windows were tightly closed and never opened from All Saints Day to Easter. It was his revolt against such unchanged air in the sick room which led to a serious cabal against his conduct of the case of Mademoiselle. When called to see the princess, who was suffering from phthisis, he found her in such a close, fetid room that he impulsively exclaimed "The princess is being poisoned" and ordered the windows thrown open at once. The remark was at once reported, and with courtly alacrity the rumor spread of Tronchin's charges against the medical and court attendants. A serious quarrel arose, and it was some time before the suspicions and recriminations were allayed.

In the matter of diet he urged simplicity and abstemiousness, and the ingestion of abundant water. His letters are full of the most detailed advice upon these subjects, and show a practical judgment in dietetics which the present-day knowledge of physiology can only confirm. They are, too, models of clear simple language, within the easy comprehension of the patient.

Exercise, especially in the open air, was the third text of all his teaching. "Chop your own wood" he directs one nobleman, quite as Abernethy in England later told his gouty patient to "live on a shilling a day, and *earn* it."

> You must take constantly and regularly as much exercise as you can without fatigue. Use will gradually make it easy. Riding a horse is preferable to all other forms.

For the court ladies the idea of actual bodily exercise out of doors was a most startling novelty, but such was the insistence and personal influence of this great new physician that the early morning walk out of doors in low shoes and simple dress soon became the fashion. The long, staff-like canes, which we know in pictures of the time, were

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Tronchin's device, and ordered by him at first as aids and support for those unused to walking, and as a means of inducing greater exercise of the arms. The short, unpadded skirts were called "tronchines," and the correct idiom of the day among smart society for the constitutional stroll, staff in hand, was "tronchiner"—"to Tronchin."

A sedentary life was in his opinion rigidly to be avoided, and his letters are constantly referring to it.

> Of all the causes which enfeeble the human body a sedentary life is one of the most formidable. You must lead an active life, sleep only seven hours, *and renew* the air of the room you occupy

is part of a letter he writes to the Marquis de Vance. So great was his disapproval of sedentary habits that he urged the nuns in cloisters where their vows prevented exercise in the gardens, to walk regularly up and down even in the cubicles of their retreat. For clerks in counting-houses he invented the standing desk, but, with his usual thoroughness in detail, had them made so as to be raised or lowered to the proper individual requirements. He advised their use for students as a change from always sitting over their books.

One of his recommendations was that pregnant women be allowed to go out of doors and exercise. It is hard to look upon this as startling, but it was little less than revolutionary, for it was then the custom among persons of noble rank absolutely to forbid all such movements to women when *enceinte.*

In matters of dress he advocated simplicity, and opposed the swathing of the neck in high heavy clothes. He disapproved the wearing of the huge and heating wigs which were then the fashion, and preached against their unhealthfulness. He wore himself in public only the small light wig as a necessary concession to custom and his social position. At home he always hung it on a peg in the library.

He was deeply interested in the upbringing of children: to secure for the rising generation sound bodies hardened by temperance and exercise. He devised a simple little suit of soft leather, much like the present-day jumper suits, for children, and babies to be in style were "jacketed *à la* Tronchin."

From even this very brief account it is easy to see that Tronchin's

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purpose was already to strengthen the frame, increase the powers of resistance, and by hygienic living to avoid rather than to treat diseases. "With sobriety and exercise one will have little need of physicians or druggists," he says to one patient. Yet he was well aware of the need of directing natural processes, checking or stimulating by medical means as the case might require. He was trained in the pathology of his day, and recognized as one of the best pharmacologists of his time.

If in reading his letters of medical advice upon health and physical hygiene, it is difficult to realize that they were written one hundred and fifty years ago, so fitting are they today; there is something even more startling in its similarity to present-day fashions in medicine, in the attitude he took toward the mental and moral factors of disease. A firm believer in the close union of body and spirit, he appreciated at their proper values the mental ailments due to visceral disease, and the bodily disturbances and discomforts whose origin lay far back in mental or moral torpor. Wonderfully sympathetic toward all who became his patients, his psychical management of the fashionable women who suffered from "the vapors" as they were then called, would be a helpful lesson to many present-day excited psycho-therapeutists. For he never confused the relationship between bodily and mental causes or effects. Witness two letters. First to the baron d'Aigunes:

The exhaustion of the strength of a spirit united so closely to the body affects the health of the body. The mind may be too active for the body, and if the body is frail it is only the sooner worn out. The physician is then called in, who often completes what the spirit's exertions have begun. He purges, pukes, and bleeds. The body is thereby only used up the sooner; because seeing only the suffering body he does not think that perhaps the root of the trouble may be in the spirit, where as a fact it is. Epictetus and Marcus Aurelius ought to be his Hippocrates and Galen—the thoughts of Seneca his materia medica. If he knew how to make use of these, he would often cure ills which appear to him incurable, or which are so without seeming so to him. Not that a body worn out by its spirit ought to have any special treatment different from that of the spirit; but always in such cases it is the mind which comes first . . . . Then rest the worn-out body, which recuperates much better by exercise and simple living than by any other remedies.

On the other hand to M. d'Angent:

Your letter, my good friend, had not a word too much. Not one less would have served to put me fully in touch with the conflict between the moral and physical jurisdictions which you have very well painted. In reviewing carefully all that has happened to you, you can at present know as well as I do, that a small derangement in the organ designed

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to secrete bile may make a Plato into an Orestes, or an Epictetus into a misanthrope. Here is the moral of it which you must keep in mind, that spite of all that the faddists of the age may say, the wise man has nevertheless much the advantage of the fool, were it only in being able by his wisdom to prevent many of the physical derangements which overthrow or destroy moral nature: and it is just herein that the triumph of temperance consists, which moving on like Justice, with scales in hand, counts as true pleasures only those which are free from penalties.

There is no confusion here, or muddling of psychical with functional disorders: only the calm judgment of a sober mind well grounded in the knowledge of the facts of anatomy and physiology. In the higher realm, too, of spiritual and religious influences as aids to the restoration of normal health of body and mind, there is evidence in all his letters of clear thinking and just evaluations.

You tell me that your situation is terrible. Allow me, in turn, to ask you a question. Have you any religion? If you have not, I pity you from the bottom of my heart. Can any situation whatsoever be terrible when you have confidence in God? I can see horror only in the situation of those who lack this confidence, and can faith in God exist without submission to his will? . . . . The truly religious man does not complain, because he knows that the trials come from God. He puts his finger to his lips and says as his last word—"Thy will be done."

Such in briefest outline was the life and practice of this remarkable man. Six feet tall, of well-filled stature, he was always a handsome man. His face was full and even-featured, with a firm chin and mouth softened by a graceful gentleness—rosy lips, black eyes, and a Roman nose. Calm and poised in manner, he commanded the instant confidence of his patients, with an authority which was speedily strengthened by the enthusiastic and friendly affection of all who came under its sway. The secret of his lasting success lay in this quiet force of character. Holding always the highest ideals of his profession, he was wont nevertheless to say, "The first requisite for a physician is that he be an honest man. Science comes after that."

The remaining years of his life were spent in busy professional and social life. His letters are full of interesting gossip of the court and intellectual circles of Paris from 1766 to 1781: little stories of the ducal card-parties lasting all night, "from which I came home played out. The ladies can sleep till noon; but such hours are not for one who has work to do." His own hospitality was generous, but of a soberer type—

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dinners to small companies of congenial and witty persons of education. His correspondence covered a wide range of subjects— from family letters telling of the presentation of Mme. du Barry, and commenting on the political and social ambitions and intrigues involved in its accomplishment, to serious discourses on the problems of life and government, which were looming ahead for all thinking men.

Blessed with his happy combination of integrity and graciousness he was at the same time respected and popular among the extravagant and frivolous society in which his lot was cast. He died in 1781. His funeral was honored by the grief and presence of noble friends, while the poor stood in crowds weeping before the door.

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# THE FENIAN MOVEMENT

By Clyde L. King

To understand the Fenian movement we must understand the American Irish of the sixties and to understand these we must go back to the conditions in Ireland in 1846–48. These were the years of the famine. On every hand there was social, economic, and industrial distress. Thousands starved and thousands more were on the verge of starvation. How to maintain life itself was the one pressing problem with all the peasantry. Their crops had failed. Evictions followed. Employment at any wage, there was none. Thousands of these poor, ignorant, unskilled peasants[1] sought refuge from starvation by emigrating to the United States.[2] Half of them, it would seem, had their passage paid by friends, being too poor to pay for it themselves.[3]

By 1850 1,300,000[4] of these Irish had landed in the United States. They knew nothing of the West with its cheap lands and its great opportunities. Even had they known of it, they would have had neither the money nor the courage to go there. Therefore, the greater portion of them remained in or near Boston, Philadelphia, and New York.[5] In 1860,[6] there were 1,611,304 natives of Ireland in the United States,[7] and 885,445 of them were still in the three states in which the above-named ports are situated. By the census of 1870, 1,217,496 of the 1,855,827 Ireland-born people in the United States were in the six New England States.[8]

Unskilled in the trades, these peasants could find employment only by doing the drudgery of the cities in which they congregated,[9] or by

[1] Byrne, *Irish Emigration*, p. 42.

[2] Bagenal, *The American Irish*, p. 74.

[3] *Niles Register*, 67, 80.

[4] Bagenal, *The American Irish*, p. 127; notes E. E. Hales, "Letters of Irish Emigration."

[5] *Edinburg Review*, p. 261, April, 1868; Bagenal, *The American Irish*, p. 65.

[6] *Census of 1860*, pp. 621–23.

[7] The total foreign born was 4,136,175. The Germans were next to the Irish with 1,302,382.

[8] In New York City there were 202,000 (21 per cent. of its population); 96,698 were in Philadelphia, and 56,000 in Boston.

[9] Of those engaged in the severest and worst paid drudgery in New York City in 1876, 50 per cent. were Irish; 20 per cent. native Americans; and 16 per cent. Germans. Comparative death rate for quarter ending March 31, 1877; Irish 24.5; Germans 15.7. Infant death rate: Irish 83 per cent.; Germans 35 per cent.—Bagenal, *The American Irish*, pp. 69 ff.



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working in large gangs on the internal improvements of the country. Such labor was poorly paid; poor pay meant poor food and poor quarters.[1] They crowded into low cellars and wretched tenements. These miserable abodes become moral cesspools. No family life was possible; no traditions could be cherished. Life in the gang, though far from the city, was but little if any improvement upon this city life. With such environment, and with the American people as a whole indifferent and unsympathetic toward them,[2] assimilation went on very slowly, if at all, and the mass of the Irish remained as distinctively Irish as they were on the day they first set sail for the United States—Irish in prejudices and attitude of mind.

The characteristic bias of mind of these Irish was their hatred of England.[3] The overwhelming majority of them had come from the Provinces of Leinster, Munster, and Connaught,[4] where this anti-English sentiment was strongest. Their life in the United States was not such as to make them forgetful of their ancient grudge. Moreover, among them were many of the exiled leaders of the Young Ireland uprising[5] of 1848, and these took great care to see that the Irish in America never ceased to be ardent lovers of Ireland and all things Irish and as equally ardent haters of England and all things English. Under such circumstances nothing could be more certain than that these Irish Americans would form revolutionary societies. The first of these societies, "The Irish Republican Union,"[6] was established in the very year that the Young Ireland Revolution failed. In 1855, a second, "The Massachusetts Emigrant Aid Society,"[6] was organized. In 1858, some forty Irish Revolutionists organized[7] the society which they happily named the Fenian Brotherhood.[8] They chose O'Mahony as the head

[1] *Edinburg Review*, p. 261, April, 1868; BAGENAL, *The American Irish*, p. 12.

[2] *North American Review*, Vol. LII, p. 205.

[3] *Quarterly Review*, p 139, January, 1868; *Edinburg Review*, p. 271, April, 1868.

[4] MCCARTHY, *History of Our Own Times*, Vol. IV, p. 132.

[5] *Irish Literature*, Vol. XI, p. xi; MCCARTHY, *History of Our Own Times*, Vol. IV, p. 132; "Proceedings of the First Fenian National Convention," p. 9.

[6] *Geneva Arbitration*, Vol. II, p. 254. (Foreign Relations Papers.)

[7] GOLDEN SMITH, *United Empire*, Vol. II, p. 507; MCCARTHY, *History of Our Own Times*, Vol. IV, p. 132.

[8] There was an air of Celtic antiquity and mystery about the word "Fenian." Finna was the name of an ancient Celtic caste of warriors.

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of the organization, giving him the title, Head Centre. He received his commission, he avers,[1] "from elsewhere," probably, that is, from one or both of the revolutionary societies in Ireland. The Brotherhood was organized for the purpose of gaining the independence of Ireland. It was not an agitation for remedies, but a conspiracy for revolution.[2] It looked for no triumph save a triumph of arms.[3]

The Brotherhood, from the first, had no strong natural leaders. For some reason, ostensibly because it was thought to be a secret order, the Catholic clergy were bitterly opposed to the movement. Nor did it find support among the Protestant Irish or among the Irish gentry. It was thus deprived of the two classes from which alone intelligent and competent leadership could come. The members of the Brotherhood were from the peasant class[4]—day laborers and servant girls. Its leaders and organizers, save those that were professional revolutionists, must come from this class. The average local leader of the movement, therefore, was ignorant and incompetent[5] with no grasp upon the tremendousness of the task of dismembering the world's great empire. As it was not a movement seeking to solve peaceably the great Irish problems of the day, it did not attract the best of the Irish thinkers. It had but few poets[6] and little literature. Deprived of the columns of the Catholic Irish journals, it had to create its own journal. For general notices, it made use of such of the American papers as were catering to the Irish vote.

During the first two or three years of its life, the Brotherhood had a slow but steady growth. Local orders ("Circles") were organized throughout the whole country, south as well as north. Urged on by the leaders, many of the Fenians joined the militia[7] of their respective

[1] *Proceedings of the First National Fenian Convention*, pp. 6 and 8.

[2] Said one of the Fenians: "Is it so very difficult for you to understand that the Irish people want to be rid of England altogether—that they would rather have bad laws of their own making than good ones of yours, and that no possible reforms would be acceptable to the Irish people?"—Quoted from a Fenian Magazine in *Quarterly Review*, p. 137, January, 1868.

[3] *Proceedings of the First Fenian National Convention*, p. 6; also *The Nation*, Vol. II, p. 296.

[4] *Quarterly Review*, p. 266, April, 1868.

[5] As an example see the biography of P. H. Simnot in *Providence Daily Journal*, p. 1, January 9, 1866.

[6] CHARLES KIRKHAM, JOHN CASEY, and ELLEN O'LEARY, *Irish Literature*, Vol. III, p. xi.

[7] *Edinburg Review*, p. 265, April, 1868.

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states. This idea seemed especially popular in Massachusetts. The *Edinburg Review* of April, 1868,[1] says that before the Civil War broke out, the Fenian secret army in the United States was 30,000 strong. This, no doubt, largely over-estimated the Fenian strength at this time yet other sources seem to indicate that the number of Fenians that joined the militia in order to acquire efficiency in military tactics was considerable. At the call to arms in 1861, members of the Brotherhood enlisted in large numbers in both armies. In order to keep "green" the final mission of the organization, many Circles were formed in both the army and navy of the North,[2] the connection with the southern Circles having been necessarily severed at the outbreak of the war.

With the progress of the Civil War there was aroused in the United States a feeling of dissatisfaction with Great Britain because of her attitude toward the southern Confederacy. This discontent grew into bitter resentment and irritation. War was imminent. This attitude of hostility furnished ideal conditions for the growth of the Fenian Brotherhood. Among the Irish the old antipathy toward the English was aroused anew and the prospects of war between the United States and England offered a rare opportunity for launching a revolution for the independence of Ireland. Elated with the prospects of success, the members of the Brotherhood contributed liberally toward the financial support of the venture. A general desire to embarrass Great Britain elicited contributions from the northern people generally and opened the columns of the papers to the propagation of Fenian doctrines.

The first National Congress of the Fenians was called to meet in Chicago in November, 1863. Three hundred delegates,[3] representing[4] thirteen states, seven British Provinces, and many army and navy organizations,[6] assembled at the appointed time. The meetings of the convention were secret and none but delegates and "Centres," unless by

[1] P. 518.

[2] *Proceedings of the First Fenian National Convention*, p. 8.

[3] So reported. Only 100 signed the resolutions, however

[4] *Proceedings of the First Fenian National Convention*, pp. 5, 6, 43–48.

[5] Pennsylvania, Illinois, Massachusetts, New York, Indiana, Kentucky, Tennessee, Ohio, Wisconsin, Missouri, California, Kansas, and the District of Columbia.

[6] Army of the Potomac; Army of the Tennessee; Army of the Cumberland; Circle of the Rappahannock; also delegates from the Irish Legion, 69th N. Y., the 84th Pa. Vols., 23d Ill. Vols., 10th Ohio, 42d N. Y. Vols., 97th N. Y., 14th U. S. Infantry, 35th Ind., Phoenix Brigade, N. Y., and the Circle of U. S. Engineers.

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special vote, were admitted. O'Mahony in his opening address[1] stated the purposes of the convention to be: (1) "to place the organization in a position more suitable to its vast extent and to pass such rules for its direction and management as will render it more efficient and more ready to the hand than it is at present;" (2) "to frame a constitution and a code of by-laws;" (3) "to declare our object and our resources before the world, so that all the friends of Irish freedom may understand us."

The convention framed a constitution.[2] By this constitution the Brotherhood was changed from one purely military in character to one civil as well as military. The local societies, the constitution provided, were still to be called Circles and were to be presided over by Centres. For the convenience of its membership, each of the larger Circles could have Subcircles. The presiding officer of the Subcircle was the Subcentre. Over the Circles of each state was a supervisory and administrative official known as the State Centre. Over the State Centres was the national organization with the Head Centre as the chief official. The Head Centre was to be elected annually by a general congress of the Fenian Brotherhood, this election to be subject, however, to the acknowledgment of the "C. E. and I. R. B."[3] This general congress was also to elect, upon the nomination of the Head Centre, a central council of five Centres, and a central and an assistant treasurer. The constitution gave extensive and summary powers to the Head Centre. Not only was he to nominate the officials above mentioned, but he was to appoint and have full control over the State Centres, who in their turn had full control over the Circles in their respective states. Even the Centres, though elected by their respective Circles, could not be commissioned without first receiving the approval of the Head Centre. The Centres were to have great power, especially in case of a call to arms. The organization of the Brotherhood was now, indeed, one "ready to the hand," and certainly in the hands of a strong leader would make a powerful military weapon.

The constitution declared that the Fenian Brotherhood was a "distinct

[1] *Proceedings of the First Fenian National Convention*, pp. 5, 6.

[2] *Proceedings of the First Fenian National Convention*, pp. 46 ff.

[3] Two revolutionary organizations in Ireland. The latter was "The Irish Revolutionary Brotherhood."

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and independent" organization composed of "citizens of the United States of Irish birth and lineage and the friends of Ireland living elsewhere on the American continent and in the Provinces of the British Empire wherever situated." It also stipulated that each member should take the following pledge:

> I, ———, solemnly pledge my sacred word of honor as a truthful and honest man, that I will labor with honest zeal for the liberation of Ireland, from the yoke of England, and for the establishment of a Free and Independent Government on the Irish soil; that I will implicitly obey the commands of my superior officers in the Fenian Brotherhood; that I will faithfully discharge my duties of membership as laid down in the constitution and by-laws thereof; that I will do my utmost to promote the feeling of love, harmony, and kindly forbearance among all Irishmen; and that I will foster, defend, and propagate the aforesaid Fenian Brotherhood to the utmost of my power.

The constitution fixed the minimum weekly dues at five cents and the minimum initiation fee at one dollar, leaving to each Circle power to impose larger fees. Each Circle and Subcircle was to meet once a week. From all meetings, discussion upon religion or American politics was to be "peremptorily excluded."

The convention adopted a long series of resolutions[1] which, by special vote, they entitled "The Declaration of the Independence of Ireland." The first of these resolutions declared that the Brotherhood would use every honorable means to gain the independence of Ireland save such as were in violation of the constitution and the laws of the United States. The second declared that war was fast approaching between the United States, their "adopted country" and England, their "hereditary enemy" and so decreed that the young men of the Brotherhood should "apply themselves 'sedulously' to the study of military tactics and the use of arms" . . . . and should organize themselves into companies, "so as to be prepared in case of war to offer their services to the United States Government by land or sea, against England's myrmidons." The eighth proclaimed the "undying love" of all Irishmen for Ireland and their "intense and undying hatred toward the monarchy and oligarchy of Great Britain which have," the resolution continued, "ground their country to the dust, hanging her patriots, starving out her people and sweeping myriads of Irish men, women and children off their parental

[1] *Proceedings of the First Fenian National Convention*, pp. 20 ff.

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fields, to find a refuge in foreign lands, bringing with them thither a burning desire for the destruction of British tyranny, and bequeathing this feeling as an heirloom to their posterity." The ninth pointed out that the first step toward the disenthrallment of Ireland from the "fell tyranny of Great Britain" was to form a close alliance between "the Irish citizens of the American Republic," those still living on Irish soil, and "those expatriated Irishmen, who are planted by thousands like so many hostile garrisons" throughout all Great Britain. Several of the resolutions dealt with the "C. E." and "I. R. B." but these were not printed. In another of the resolutions, the convention avowed that the Irish should prepare at once for Freedom's battle, and by another they resolved that the Irish people constituted "one of the distinct nationalities of the earth and as such is justly entitled to all the rights of self-government."

The convention also adopted an "Address[1] to the People of Ireland." The address, in part, read:

> We are solemnly pledged to labor earnestly and continuously for the regeneration of our beloved Ireland. That pledge, with the blessing of Divine Providence, we shall redeem, and when the wished-for hour will have arrived, we shall be prepared with you to meet the implacable persecutors of our race in battle array, to put an end forever to the accursed system under which our unhappy people have suffered such cruel tortures or die in the attempt. . . . . We are thoroughly convinced of the utter futility of legal and constitutional agitations, parliamentary "policies" and all similar delusions. . . . . Americans already admit that the non-recognition of the revolted States by England is due to the attitude which the Irish people have assumed, both at home and in this Republic. If the Irish people at home and abroad were united in a band of brotherhood for the salvation of their own country, would the United States hesitate for an hour to strike a blow which would be followed by two inevitable results—peace in America and liberty in Ireland? . . . . Here we have soldiers armed and trained . . . . with able and experienced generals to lead them. . . . . We have but to act as becomes brave and reasoning men, and ours shall be the pride and the glory of lifting our sorrowing Erin out of the streams to her place among the nations. *Brothers rely upon us. We rely upon you.*

Perchance excerpts from one of the addresses delivered at the convention will give us still a better insight into the ruling spirit and trend of the movement. After passing in review the long "vista of ages" the orator[2] said:

[1] *Proceedings of the First Fenian National Convention*, pp. 55 ff.

[2] James Gibbons of Philadelphia, chairman of the Committee on Resolutions and Addresses.

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What seas of tears and blood, what sufferings and what sorrows pass before me. . . . . But the men of Ireland have resolved not to die the dog's death of starvation; they have resolved to die as the descendants of a brave race should die with the flag of Irish liberty in their hands. The Fenian Brotherhood, like true engineers, have surveyed the paths which they must traverse and they have discovered that they will have to tread the same bloody paths their fathers trod before them. They know that liberty is not a gift—that it must be wooed and won by virgin steel in the hands of free men, and they have resolved to win it—planting the standards of Ireland, a free land, upon the mounds where lie those foes who have been feeding upon the hearts' blood of her people for ages.[1]

The convention gave a great impetus to the growth of the Brotherhood. Pamphlets, containing the constitution, the resolutions, and addresses of the convention, were distributed[2] among all the Circles. The Brotherhood grew rapidly from now on. The enthusiasm spread to Ireland. Within a month Stephens[3] started in Dublin, not a stone's throw from the Lord Lieutenant's castle, the *Irish People*[4] for the sole purpose of disseminating Fenian doctrines. Through its columns he preached nationalism and insurrection.[5] Secret meetings had been held in Ireland since 1862. Now emissaries from the United States organized Circles, enlisted volunteers, and perfected the military organization.[6] Armories were established and the volunteers were schooled in the manual of arms. The campaign was carried into England itself and soon every English town, with an Irish element, had its confederacy[7] of shoemakers, tailors, clerks, and hodmen. In Ireland and England this had to be done with the greatest secrecy, but in the United States all this, and much more, was being done openly. A lively campaign was carried on for members and for funds. In March, a bazaar held in Chicago netted, it was said, $55,000. The annual congress of 1864, held in Chicago, was widely attended.

With the year 1865, the Brotherhood assumed a decidedly belligerent attitude. It was now evident that the Civil War would soon be over. The society would then have trained soldiers and experienced commanders. The feeling of bitterness toward Great Britain was still very strong in the United States and many people were looking forward

[1] *Proceedings of the First Fenian National Convention*, p. 17.
[2] Twenty thousand of them were ordered printed for this purpose.
[3] One of the "Young Irelanders" of 1848.
[4] *Contemporary Review*, Vol. 19, p. 305.
[5] *Contemporary Review*, Vol. 43, p. 456.
[6] LALOR, Vol. II, p. 172.
[7] *Edinburg Review*, p. 270, April, 1868.

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to the close of the Civil War for an opportunity of bringing Great Britain to terms, going to war, if need be, to do so. The Fenians themselves might bring on complications which would force war, if other causes did not, their leaders argued. If war did not ensue, American assistance in some form could certainly be relied upon, for if all other means should be of no avail, there was left the Irish vote which never yet had failed to rally succor for the Irish cause.

At the annual Fenian convention of 1865[1] (held in January at Cincinnati) definite plans were laid for an Irish rebellion. O'Mahony announced to the convention, indeed, that they were already "virtually at war" with Great Britain. During the next few months, money[2] and men were sent to Ireland.[3] In fact, so great was the influx of strangers into Ireland—strangers with Celtic features and with the bearing of American soldiers—that the Irish authorities took alarm. Their fears were intensified when the news of the great activity of the American Fenians reached them. They decided to take summary measures of suppression. On September 15, 1865, the Dublin police swooped down upon the office of the *Irish People*,[4] arrested its leading editors and their accessories, including Stephens himself, and seized many incriminating private documents. With these documents as a clue, other arrests and imprisonments were made in all parts of Ireland. This decisive action put an effective damper upon the revolutionary activities of the Irish wing of the Fenian Brotherhood. The English, however, were now for the first time fully aroused to the portentous dimensions of the movement.[5]

Defeat in Ireland seemed to arouse all the latent energy of the Fenians in the United States. In October[6] a general convention was held in Philadelphia.[7] Reports were given as to the status of affairs in the

[1] *Geneva Arbitration*, Vol. II, p. 254; *Contemporary Review*, Vol. XIX, p. 307.

[2] Five thousand pounds were intercepted by the Irish authorities in two weeks, *Diplomatic Correspondence*, 1865, Vol. I, p. 574.

[3] McCarthy, *History of Our Own Times*, Vol. IV, p. 137.

[4] *Harpers' Weekly*, p. 2, October 28, 1865; *Contemporary Review*, Vol. XLIII, p. 760; *Edinburg Review*, p. 265, April, 1868; *Contemporary Review*.Vol. XIX, p. 309; Lalor, Vol. II, p. 173; McCarthy, Vol. IV, p. 137

[5] See excerpt from *London Times* in *Diplomatic Correspondence*, 1865, Vol. I, p. 574.

[6] 1865.

[7] *Geneva Arbitration*, Vol. II, p. 254; Lalor, Vol. II, p. 173; *Contemporary Review*, Vol. XIX, p. 309; *Annual Cyclopedia* of 1865, p. 334.

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Emerald Isle. This convention was probably the beginning of a broil later to do sad havoc to the Fenian cause. The constitution was amended. Part of O'Mahony's power was taken from him, it appears, and vested in a Senate (which took the place of the Executive Council) and a House of Representatives. The bone of contention was the problem as to what was the best method of starting the next affray for the independence of Ireland. One faction, led by O'Mahony and backed by Stephens,[1] wanted to foster a second rising in Ireland. The other faction, led by Roberts and Sweeney, wanted to begin the affray by an invasion of Canada. The convention sent a delegation to Washington, which announced[2] on its return that the President and Senate favored this plan of seizing British territory in America.

Although the members of the convention were divided as to the best method of opening the conflict, all were a unit in thinking that the hour for winning the independence of Ireland had come. To this end they once again declared the Irish Republic to be a free and independent nation. They issued bonds in the name of the republic, redeemable six months after the acknowledgment of its independence.[3] New York City was decreed to be the temporary capital of the Irish nation.

The convention over, O'Mahony opened up in New York City spacious headquarters. He appointed a minister of war, a minister of the navy, and a minister of finance.[4] These shared his executive mansion[5] with him. Great care was taken to reorganize the Fenian army, special pains being taken to give it its full quota of generals, major-generals, and colonels. One of the first measures of the new Irish Republic was to levy an income tax. But the opposing factions could not be reconciled and within three months the broil[6] was waxing warm indeed. O'Mahony

[1] Who had in the meantime skilfully escaped from prison.

[2] *Contemporary Review*, Vol. XIX, p. 309.

[3] "It is hereby certified," read these bonds, "that the Irish Republic is indebted unto———or bearer in the sum of ten dollars redeemable six months after the acknowledgment of the independence of the Irish nation, with interest from the date hereof inclusive, at 6 per cent. per annum payable on presentation of this bond at the treasury of the Irish Republic."—*Geneva Arbitration*, Vol. II, p. 254.

[4] LALOR, Vol. II, p. 173; *Geneva Arbitration*, Vol. II, p. 254.

[5] Rental $1,200 per year.

[6] *Providence Daily Journal*, January 2, 5, 8, and 15, 1866; also May 1, 4, 12, and 17, 1866.

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called for another general congress[1] which met[2] in New York on January 3, 1866, with 500[3] delegates in attendance. The Senate, of which Roberts was president, refused to convene, not recognizing the legitimacy of the call for the Congress. The Congress supported O'Mahony, his plan of carrying the war directly to Ireland was approved, and the Chicago constitution was readopted, thus giving O'Mahony full sway once more. Thus supported, he issued a war circular[4] and sent money, men and arms to Ireland.

With the prospect of aid from the United States, the Irish contingent of the Brotherhood took fresh courage. Charles Francis Adams, our ambassador at the court of St. James,[5] reported to Secretary Seward that the Fenian organization was "spreading in every direction carrying with it many of the more intelligent class of the tenantry, and even compelling the acquiescence of some of the priests."[6] Soon the island was once more in chaos and revolution was imminent. American Fenians, pouring into the island, added to the turmoil.[7] Business stopped. Industry came to a standstill. Panic ensued. The gentry barricaded their doors and the Protestant Irish talked of civil war.[8] The Irish officials saw that if they were to thwart the revolution at all, more decisive measures would have to be taken than those they had taken four months before. They therefore urged Parliament to repeal, quickly and secretly, the writ of habeas corpus. Parliament did so.[9] The moment the writ was repealed, the Irish police swooped down upon the unsuspecting conspirators and clapped them into jail.

Parliament had acted on Saturday (January 17, 1866), an unusual day for such business. The reasons given by the government for request-

[1] *Providence Daily Journal*, January 3, 1866.

[2] A guard of 22 men from the 99th N. Y. state militia refused admission to all not provided with credentials, *Geneva Arbitration*, Vol. II, p. 255; *Providence Daily Journal*, January 3, 1866.

[3] *Providence Daily Journal*, January 2, 3, and 5, 1866.

[4] *Contemporary Review*, Vol. XIX, p. 311.

[5] *Diplomatic Correspondence*, 1866, Vol. I, p. 58.

[6] "Thus far," he continues, "the Orange party, though much alarmed, has committed itself to no overt effort at counteraction, so that things wear an appearance of calm which is not warranted by the reality."

[7] LALOR, Vol. II, p. 173.

[8] *Diplomatic Correspondence*, 1866, Vol. I, p. 58; LALOR, Vol. II, p. 173.

[9] *Contemporary Review*, Vol. IX, p. 309; *Diplomatic Correspondence*, 1866, Vol. I, p. 69; MCCARTHY, *History of Our Own Times*, Vol. IV, p. 122; LALOR, Vol. II, p. 173.

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ing such a hasty and secret repeal of the writ were:[1] (1) The rapid spread of the Fenian organization over "great counties, wide districts, and whole provinces;" and (2) the desire to pounce without a moment's warning upon numbers of "native" Irish claiming to be naturalized American citizens. The suspension met with opposition, particularly from Bright, who seized the opportunity to enlarge upon the wrongs[2] of Ireland. But the measure passed and for some weeks after its passage the summary arrest[3] over in Ireland of all Irishmen who had the slightest appearance of being Americans went merrily on[4]—that is,the arrest of all that they could find, for the moment the officials began making arrests the Irish Americans beat a hasty retreat to the United States.[5] Within a couple of months, quiet once more prevailed in the Emerald Isle.[6]

This effective quietus upon the revolution was decisive proof to the Roberts-Sweeney faction that the proper way to begin the conflict was to acquire Canadian territory. It was so accepted by the majority of the Fenians. Therefore plans were at once perfected and hurried to completion for the Canadian invasion, O'Mahony, for the time, losing his grip upon the Brotherhood. War meetings were held. The treasury was replenished, not only by means of dues but by subscriptions and the sale of Fenian bonds.

The plan[7] for the invasion called for a general advance upon the Canadian frontier with the advance centered at three places: upon the Niagara frontier; upon the frontier in the neighborhood of Prescott and Cornwall; and along the line of the Richelieu. Fifty thousand Irish[8] were to be marshaled for the invading army and these were to be reinforced when they reached Canadian soil by the Canadian Irish.[9]

[1] *Diplomatic Correspondence*, 1866, Vol. I, p. 69; *Bright's Speeches*, Vol. I, p. 350.

[2] *Bright's Speeches*, Vol. I, pp. 351, 355.

[3] *Diplomatic Correspondence*, 1866, Vol. I, pp. 70, 74; LALOR, Vol. II, p. 173.

[4] On March 31 there were 670 in prison (*Contemporary Review*, Vol. XIX, p. 312). Adams thought that the most of the Americans who had been arrested were more or less implicated (*Diplomatic Correspondence*, 1866, Vol. I, p. 70).

[5] *Providence Daily Journal*, January 4, 1866, p. 1.

[6] *Contemporary Review*, Vol. XIX, p. 313.

[7] *Correspondence Relating to the Fenian Invasion* (printed by the Canadian government), p. 144.

[8] *Contemporary Review*, Vol. XIX, p. 304.

[9] The force which invaded Fort Erie brought with them a large quantity of arms to put into the hands of their Canadian allies (*Correspondence Relating to the Fenian Invasion*, p. 144); "9 wagon loads of arms and ammunition" (*Providence Daily Journal*, January 4, 1866).

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Aid would be received from the people and government of the United States, and indeed a war would be forced between this country and Great Britain. Even if this war did not ensue the United States government would recognize the belligerency of the Irish Republic, once that it had soil that it could claim as its own, and then the republic could send out privateers against English commerce.[1] Thus harrassed on the sea and with a revolution in Ireland, England, in time, would be forced to submit.

Nor was the plan so chimerical as it may at first thought appear. Many men very close to the officials at Washington were at this time evolving plans for a war with Great Britain. Senator Stewart, of Nevada, tells of a plan for such a purpose suggested by Senator Zach Chandler, of Michigan.[2] It was that the United States should send 200,000 trained veterans into Canada, 100,000 to be picked from the Federal, and 100,000 from the Confederate Army. This plan was much more visionary that the Fenian plan; yet thirty of the best minds of the Senate were won over to the proposition. Add to this probability of war the confidence among the Irish, born of long years of catering to the Irish vote, that they could get from the government all the assistance they wished, and one can see that the Fenian plan was, to the Fenian mind, well founded.

With the advent of spring, steps were taken toward the culmination of the invasion. The places of rendezvous[3] were Malone and Potsdam in New York, St. Albans in Vermont, and, chief of all, Buffalo. Despatches from all over the country told of the departure of Irish troops. From Boston, New York, Philadelphia, Cincinnati, Nashville, Louisville, St. Louis, Chicago, Cleveland, and other large cities, Fenians in companies[4] varying in size, started northward. The Cleveland Fenians

[1] "Who will say," said General Sweeney at one of the war meetings, "that Andrew Johnson will not recognize the Irish Republic, even if it should be only in name, as long as we have soil that we can claim as our own? It is necessary to have some base, from which we can send out privateers against English commerce; and by that means, I think, we can take enough to maintain a government for fifty years very respectably."—*Geneva Arbitration*, Vol. II, p. 255.

[2] For details see the account in the *Saturday Evening Post*, February 29, 1908.

[3] *Diplomatic Correspondence*, 1866, Vol. I, p. 126.

[4] Three companies from Philadelphia; four from Baltimore; three hundred men from Cincinnati; seven hundred men from Indianapolis; one hundred and fifty men from Washington; a regiment and a half from Chicago; "a large body" from Louisville; three hundred and forty-two from Cincinnati, are examples of the umbers the despatches gave.

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started on foot with green colors flying and with their officers in command; to all inquiries as to their destination they responded that they were marching to California to work on the railroad. From the places of rendezvous despatches were sent out telling of the arrival of large numbers of Irish,[1] of their secret meetings and of their probable mission. Large supplies of arms, accouterments, and ammunition[2] were forwarded to these places.[3] By May 31, all seemed ready for the invasion.

At 2:30 A. M. on June 1, an army[4] of about 900 Fenians, composed of the 7th Kentucky,[5] the 7th Tennessee, the 7th Buffalo, and a detachment from Indiana, crossed the Niagara River into Canada[6] at a point three miles north of Buffalo.[7] With green flags waving, and with wild Irish cheers, these 900 veterans of our Civil War,[8] charged upon and captured a little undefended Canadian village, Fort Erie.[9] Despatches were hurriedly sent from Buffalo by Fenian officials to the various state Centres urging them to hurry on their quota of men as the invasion had been successfully begun.

But the Canadian authorities were fully apprised[10] of all the details of the movement, as all must have been who read the American newspapers at all. The Canadian militia had been called out and part of them stationed at Fort Colborne.[11] When the invading army was launched, the mayor of Buffalo sent a telegram to that effect to the mayors of Toronto and Hamilton.[12] Thereupon the militia were hastened toward Fort Erie. About 8 A. M. Saturday morning, June 2, 1,400

[1] Estimated at 10,000 at each of the places of rendezvous.

[2] The amount of money expended may be gleaned from the fact that in one night $1,000 in bonds was sold in Nashville and $2,000 was raised in subscriptions in Boston.

[3] *Geneva Arbitration*, Vol. II, p. 256.

[4] *Harpers' Weekly*, June 23, 1866; *Correspondence Relating to the Fenian Invasion*, pp. 140, 600; *Providence Daily Journal*, June 2, 1866.

[5] Fenian nomenclature.

[6] Cutting all telegraph lines.

[7] *Correspondence Relating to the Fenian Invasion*, pp. 140, 141.

[8] *Providence Daily Journal*, June 2, 1866; both Federal and Confederate.

[9] "Large numbers of persons are reviewing the sight from the shore"—Despatch from Buffalo to *Providence Daily Journal* of June 2, 1866.

[10] Buffalo "swarmed with Canadian spies."—*Providence Daily Journal*, June 2, 1866.

[11] *Correspondence Relating to the Fenian Invasion*, pp. 140, 141.

[12] *Providence Daily Journal*, June 1, 1866, p. 4.

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Toronto volunteers, "The Queen's Own," largely made up of students, came upon the Fenians lying "encamped in the bush." They attacked, but by the time two or three dozen of their number were killed or wounded they became fully convinced that they were overwhelmingly outnumbered so retreated.[1] Twenty-one of Erin's most devoted sons were killed or wounded in the affray. During Saturday other Canadian forces arrived and by nightfall Colonel O'Neill,[2] who was in command of the Fenian army, had decided that the better part of valor was to return to Buffalo. That night, without taking the trouble of calling in his sentinels or warning the stragglers, he embarked in his canal boats[3] for the American side. But no sooner had his tugs gotten the canal boats well started than the United States steamer "Michigan," which had been lying in the port at Buffalo all this time, appeared on the scene, relieved the tugs of their precious load, and itself hauled the canal boats, Irishmen and all, into Buffalo. Here the United States district marshal put the entire army under arrest.[4]

Although this was the most effective measure, it was not the first one taken by the United States authorities to prevent the Fenians from breaking our neutrality laws. As early as May 21, they began to seize and confiscate Fenian arms, seizing on that date, so the *Providence Daily Journal*[5] reported, 87 cases of arms in Erie, Pa. Ammunition and arms were seized at other places, especially after June 1. The more notable seizures[6] were at New York City,[7] Buffalo,[8] Potsdam, Ogdensburg, and St. Albans. On June 1, detachments of regular troops were ordered to Buffalo. General Meade himself went to the frontier. The revenue cutters were called in.[9] The United States

[1] *Providence Daily Journal*, June 11, 1866, p. 2; *Diplomatic Correspondence*, 1866, Vol. I, p. 126.

[2] "A Confederate General," *Harpers' Weekly*, June 23, 1866; *Providence Daily Journal*, May 5, 1866.

[3] They crossed over in four canal boats drawn by two tugs.

[4] Seven hundred were thus arrested (*Diplomatic Correspondence*, 1866, Vol. I, p. 126). Later a body of Fenians crossed into Canada from St. Albans, and another band threatened Prescott, Can., aiming at the Ottawa, but both were easily driven back by Canadian troops (*A Short History of the Canadian People*, p. 469).

[5] May 22, 1866; despatch from New York.

[6] *Correspondence Relating to the Fenian Invasion*, p. 144; *Geneva Arbitration*, Vol. II, p. 257 (names also Erie, Oswego, Pittsburg, Malone, and Troy).

[7] "A small number of arms with a large mass of ammunition."—*Diplomatic Correspondence*, Vol. I, p. 126.

[8] In all 20 boxes valued at $2,000 (*Geneva Arbitration*, Vol. II, pp. 257, 258; from *New York Times*).

[9] *Diplomatic Correspondence*, 1866, Vol. I, p. 126; *Providence Daily Journal*, June 2, 1866.

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marshals no longer hesitated to make arrests. On June 5 the arrest of all the Fenian leaders was ordered,[1] and on June 6 President Johnson issued a proclamation[2] warning all citizens of the United States not to break our neutrality laws.

In the face of such unexpected opposition from the United States the Fenians on the frontier became discouraged and sullenly returned homeward. During the first weeks of June many new recruits landed in the places of rendezvous but these, likewise, after sizing up the situation, returned to the shovel and the hod.

The energy of the Brotherhood was now centered on the old plan, that of beginning the fight by an uprising in Ireland. Plans for a simultaneous outbreak in Ireland and in England were drawn up by Stephens. As before, Irish-Americans,[3] in small groups, if in groups at all, were to sail quietly for Ireland. The Irish and English societies were to call out their military organizations. Cluseret,[4] of France, was chosen to command such forces as were to be raised in England. His army, he was promised, should, at the first, be no less than 10,000 strong. The day appointed for the uprising was some day of January, 1867. By that time arms would have arrived from the various places in Ireland and England and, as well, from the United States. But only 700 of Cluseret's promised army of 10,000 gathered on the appointed day. Cluseret tells us that he refused to launch a revolution with such a small force and so left England disgusted. But the little army could not content themselves with returning home without any sort of a demonstration, so planned a raid on Chester, England. An accomplice revealed the plan and the attack failed.

In Ireland, an outbreak was planned for the early morning of March 6. Once more the Irish-Americans surged into the island. American arms and munitions found their way over also. At the appointed hour some 8,000 insurgents made simultaneous attacks upon isolated stations of the Irish constabulary. But, as usual, the number of insurgents proved

[1] *Geneva Arbitration*, Vol. II, p. 257.

[2] RICHARDSON, *Messages of the Presidents*, Vol. VI, p. 433.

[3] The ringleaders of the disturbances in Ireland during 1867 were Halpin, Burke, and McCafferty, who went from the United States (*Geneva Arbitration*, Vol. II, p. 258).

[4] Cluseret gives a full account of this plan and his part in it in *Living Age*, Vol. CXIV, p. 353.

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to be much less than the Fenians expected. Those that did turn out, 3,000 in all, entered into their work half-heartedly. All the attacks were easily repulsed. Arrests followed in a wholesale manner and the last dignified attempt of the Fenian Brotherhood to gain the independence of their beloved isle ended in ignominious failure. But the excitement among the Irish population was more intense and the effect on industry was more disastrous, than during any of the previous uprisings. Of all the revolutions in Ireland, indeed, the uprising[1] of March, 1867, was the severest and most destructive.

Scattering outrages and demonstrations followed during the remainder of 1867. The most notorious of these outrages was the attempt[2] of the Fenians to rescue two of their number from the police of Manchester, England.[3] A few were killed in the affray. Three of the rescuing Fenians were captured, tried, convicted of treason, and hung. The news of the execution was received with joy in England but its reception in Ireland doomed to bitter disappointment all hopes of the English that the Irish discontent had subsided. In Dublin a great commemorative funeral,[4] participated in by 15,000 people of all classes, was held in memory of the Manchester martyrs.

In December, the revolutionary spirit again broke out in Ireland. The immediate occasion was the renewed efforts of the American Fenians and the reported departure of Stephens to the island personally to conduct an insurrection.[5] The excitement waxed warm indeed. Business, scarce revived, was again prostrated, and once more panic ensued. Then occurred, over in England, an outrage which was to arouse all Englishmen to the portentous meaning of these repeated revolutions.

[1] *Diplomatic Correspondence*, 1867, Vol. I, p. 67; LALOR, Vol. II, p. 173; the *London Times* of May, 1867.

[2] *Diplomatic Correspondence*, 1867, Vol. I, p. 149–51; MCCARTHY, *History of Our Own Times*, Vol. IV, p. 143; *Irish Literature*, Vol. VII, p. 2607.

[3] September, 1867.

[4] "The Dublin procession," says Mr. A. M. Sullivan, a persistent opponent of Fenianism, "was a marvelous display. The day was cold, wet, and gloomy, yet it was computed that 150,000 persons participated in the demonstration, 60,000 of them marching in a line over a route some three or four miles in length. As the three hearses, bearing the names of the executed men, passed through the streets, the multitude that lined the streets fell on their knees, every head was bared, and not a sound was heard save the solemn notes of the 'Dead March in Saul' from the bands or the sobs that broke occasionally from the crowd."—O'BRIEN'S *Life of Parnell*, "Irish Literature," Vol. VII, p. 2609.

[5] *Diplomatic Correspondence*, 1867, Vol. I, p. 35.

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On December 13, in London a party of Fenians, with the hope of rescuing two of their number, attempted to blow up the wall of Clerkenwell prison. Property and lives were lost. "Excitement in England," wrote Adams,[2] "ran higher than at any time since the discovery of the scheme of Guy Fawkes." Attention of the English was directed toward the condition of affairs in Ireland. Regiments were sent over to the island. Arrests were made and thus the last of the Fenian attempts at revolution was frustrated. The Fenian Brotherhood, in time, lost its social, political, and soon even its military character and, after 1870, as an effective organization, passed out of existence, but not before two more attempts were made to invade Canada from the United States.

At Fenian congresses, held in Philadelphia in November, 1868, and in New York in March, 1870, preparations were made for a second invasion of Canada. On April 9 the Canadian authorities, thinking an invasion imminent, called out 5,000 militia. On May 25 O'Neill made an attack from near St. Albans. The raid was repulsed. The United States marshal arrested O'Neill and several other leaders and seized thirteen tons of ammunition. Those arrested were convicted and sentenced to not more than two years' imprisonment. President Grant at once (October 12, 1870) pardoned them. Not a year after his pardon O'Neill made another raid into Canada (October 6, 1871) on the Pembina frontier. He was arrested and brought back by United States troops, and this time met with entire immunity.[3]

During all these attempts at instigating rebellion, the Fenians were meeting with no opposition from the United States government, save that already spoken of at the time of the invasion of Canada. In many ways, indeed, the United States was lending a helping hand. On the very day that President Johnson issued his proclamation of warning, the Fenians that were arrested on June 2, as they were returning from Canada, were released on their own recognizances, save O'Neill and two other leaders, and these were released on bail the next day.[4] The

[1] LALOR, Vol. II, p. 174; *Annual Cyclopedia*, 1865, pp. 300, 375; MORLEY, *Life of Gladstone*, Vol. II, p. 241.

[2] *Diplomatic Correspondence*, 1868, Vol. I, p. 130.

[3] *Geneva Arbitration*, Vol. II, p. 260; BOURINOT, *Canada*, p. 230.

[4] *Geneva Arbitration*, Vol. II, p. 257.

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leaders in the venture from St. Albans (Sweeney, Spear, and McMahon) were also arrested but released on bonds after a day's detention. Roberts was taken into custody in New York. His examination was begun on June 11 and on the 12th he was released on parole.

On July 23, 1866, the House passed a resolution requesting the President "to cause the prosecutions instituted in the United States courts against the Fenians to be discontinued."[1] Instructions to that effect were soon issued by the attorney-general and not one of the Fenians was ever brought to trial.[2] On October 16, the United States authorities returned to the Fenians the arms and ammunition that had been seized during May and June.[3] The "understanding" was that these arms were to be sold to Santa Anna. But it must be remembered that it was just at this time that plans were being matured for the uprising in England and Ireland, which took place in the early part of 1867. Moreover, the United States government, at its own expense,[4] employed counsel to defend the Fenians captured in Canada and held for capital offenses. For such as were convicted and sentenced to death, mitigation of sentence was secured through diplomatic channels.[5]

On July 23, 1866, the House of Representatives passed[6] a resolution requesting the Committee on Foreign Affairs to inquire into the expediency of reporting a bill applying the same regulations toward Fenian belligerents that the government of Great Britain had applied to the Confederacy.[7] On March 27, 1867, just when all Ireland was in social and industrial chaos because of the Fenian uprising the House passed three resolutions, all of which, because of their belligerent tone, gave added vigor and hope to the Fenian conspiracy.[8] The first declared the Canadian Confederacy,[9] then under consideration in

[1] *Journal of House of Representatives*, 1st sess., 39th Cong., p. 1084.

[2] *Geneva Arbitration*, Vol. II, p. 257.

[3] More arms were returned in 1868 just when the Fenians were planning a second invasion of Canada (*Geneva Arbitration*, Vol. II, p. 257).

[4] RICHARDSON, *Messages of the President*, Vol. VI, pp. 457, 458.

[5] *Diplomatic Correspondence*, 1868, Vol. I, pp. 260, 262.

[6] *House Journal*, 1st sess., 39th Cong., p. 1091.

[7] *Congressional Globe*, 1st sess., 40th Cong., p. 392. The committee, however, made no report.

[8] All were introduced by Chairman Banks, of the Committee on Foreign Relations.

[9] *House Journal*, 1st sess., 40th Cong., p. 125.

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Canada, to be dangerous to the most important interests of the United States. The second asked that all claims of foreign states or citizens for the loss of property during our Civil War be submitted to Congress before being allowed by the executive department.[1] The third extended the sympathy of the House to the people of Ireland in their efforts to "maintain their independence."[2]

But why this encouragement to a revolutionary organization and why such leniency toward the transgressors of our neutrality laws? The American people were not in hearty sympathy either with the Irish or their cause. "Certainly today the prayer of Ireland should be to be delivered from herself," declared *Harpers' Weekly* late in 1865.[3] About the same time, *The Nation*[4] averred that, "Were the Fenian movement to succeed, its result would be a worse condition in Ireland than at present. . . . . Amongst the masses of Irish there are no materials for the foundation or administration of a government based on modern ideas." "The Invasion of Canada," said the *Providence Daily Journal* (June 5, 1866) "ended as sensible men generally supposed it would end." "We believe," observed the *Edinburg Review* of April, 1868, "that the dislike of the Irish by native Americans is rather increasing than diminishing." It was not a high idealism of the Irish cause on the part of Americans that led the government to assume the attitude it did toward the Fenians. It was for two very different reasons that Uncle Sam espoused the Fenian cause. The first of these was that the Irish did their "full share" of voting, and the second was that by the encouragement of this conspiracy the United States could force England into settling certain of the vexed problems raised during the Civil War.

The Irish vote up to this time had been cast almost solidly for the Democrats but, by favoring the Fenian cause, since Johnson had apparently opposed it,[5] the Republicans of the House sought to win over the Irish vote to Republican ranks. Hence the resolution requesting the

[1] *House Journal*, 1st sess., 40th Cong., p. 125.

[2] *House Journal*, 1st sess., 40th Cong., p. 125; *Congressional Globe*, 1st sess., 40th Cong., p. 392.

[3] October 28, p. 1.

[4] September 28, 1865, p. 391.

[5] By issuing his warning proclamation and by ordering the arrest of the returning army and, later, of all leaders of Fenian movement.

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abandonment of Fenian prosecutions and the ready acquiesence of Johnson in the request of July, 1866, just when the heated congressional election of 1866 was fairly launched. In March of 1867 the contest was on between Johnson and the Congress. Debate ensued in the House over the adoption (March 27, 1867) of the resolution of sympathy for Ireland. This debate reveals that the representatives were interested more in enticing Irish sympathy for the Republican cause than in avowing the sympathy of the House for the cause of Ireland. Said Representative Robinson of New York: "Irish intellect today governs the world; Irish intellect is good enough to govern England. Even the poorer sort of Irishmen like the late Duke of Wellington, proves good enough for that business. Irish intellect today is uppermost in all the transactions of England. She rules in her Parliament; she directs her press; she commands her armies; she fights her battles"[1]—excellent campaign thunder this, it must be admitted.

Nor is there any doubt that the House hoped that its resolution of sympathy for the "people of Ireland" would be interpreted by the Fenians and others as a public approval of the Fenian Brotherhood. An amendment[2] to the resolution was offered declaring that "the present Fenian movement must prove entirely abortive in bringing relief to Ireland." This amendment met with a storm of disapproval. "It is idle," said Eldridge, of Wisconsin, "for us to express sympathy with the cause of Ireland and at the same time deprecate every measure which the people of Ireland take for her alleviation."[3] "The country well knows as the House knows," declared Wood, of New York, "that the present agitation in Ireland looks to the establishment of free government in that island as the result of this same Fenian movement. We all know it is this Fenian movement that has effected military organization in Ireland, and that every rebel in arms in Ireland and all the preparatory arrangements looking to the establishment of an independent government in Ireland have been promoted, if not originally prompted, by the Fenian movement."[4] The amendment was lost 102 to 10.[5]

[1] *Congressional Globe*, 1st sess., 40th Cong., p. 392.
[2] *Congressional Globe*, 1st sess., 40th Cong., p. 393.
[3] *Congressional Globe*, 1st sess., 40th Cong., p. 394.
[4] *Congressional Globe*, 1st sess., 40th Cong., p. 394.
[5] *Congressional Globe*, 1st sess., 40th Cong., p. 394.

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Then, too, this policy of passive and, at times, of even active assistance to the Fenian Brotherhood was the means by which the United States forced Great Britain to settle certain questions then in controversy between the two countries.

Great Britain knew that the Fenian conspiracy must be overthrown before Ireland would again enjoy peace and industrial progress. For two long years the island had been in a furor of excitement and panic reigned a great portion of the time. The actual loss due to depreciation of property and stagnation of business was enormous. No one could know at what moment the mass of the Irish would rise in rebellion against "British tyranny." For such a widespread unrest there must be some adequate cause and this all England came to realize. For the first time the majority of the English acknowledged that the Irish had grave and serious grievances against England—grievances which any people would be justified in redressing by an appeal to arms—and demanded that Parliament should redress the most apparent of these grievances.[1] Gladstone took up this demand and within a week after the Clerkenwell explosion publicly declared[2] for an Irish policy along Irish lines.[3] The disestablishment of the Irish church in 1869 and the Irish Land Act in 1870, despite the declaration of the Fenians that all such parliamentary measures were "delusions," were the first great fruits of the Fenian movement.[4]

But legislation, however wise and however quickly enacted, could not prevent uprisings in Ireland so long as those uprisings were incited and supported by the Fenians in the United States. American support of Irish revolution must be done away with and both England and the United States well knew that this could be done effectively only by

[1] *Quarterly Review*, January, 1868, pp. 133–47; *Edinburg Review*, January, 1867, p. 105; McCarthy, *History of Our Own Times*, Vol. IV, pp. 239, 240.

[2] Speech at Southport, Morley, *Life of Gladstone*, Vol. II, pp. 241–43.

[3] He said: "When the habeas corpus act was suspended, when all the consequent proceedings occurred, when the tranquillity of the great city of Manchester was disturbed, when the metropolis was shocked and horrified by an inhuman outrage, when a sense of insecurity went abroad far and wide, . . . . when the inhabitants of the different towns of the country were swearing themselves in as special constables for the maintenance of life and property, then it was when these phenomena came home to the popular mind," and led the English people generally to espouse the cause of Irish reform.

[4] In Canada the Fenian invasion gave a great impetus to the adoption of the Confederation because it taught the necessity of union. See, e.g., Bourinot, *Canada*, p. 213.

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removing the causes of ill will between the two peoples. This meant the settlement by Great Britain of certain questions in the way the people of the United States thought they ought to be settled.

The first concession that Great Britain was forced to make was to recognize fully the right of expatriation. The controversy arose over the status of the American-Irish, claiming to be naturalized American citizens, who were arrested at and after the suspension of the writ of habeas corpus. The British government held that Irishmen born in Ireland were still subjects of the British Empire and their taking out naturalization papers in the United States had in no way destroyed their British citizenship. The United States held, of course, that these naturalized citizens were no longer subjects of the British crown but citizens of the United States and as such entitled to her protection.[1]

At first the British authorities in Dublin refused to allow the American consul even to visit those Ireland-born Americans who claimed his protection on the grounds that they were citizens of the Great Republic. Seward insisted that this attitude of the British government "awakened a general feeling of resentment" in the United States and "deeply wounded our pride of sovereignty." He pointed out, too, that over this very problem the Fenians were hoping to involve the two countries in war. For Great Britain to insist upon the application of her theory of citizenship meant to give greater sympathy for and impetus[2] to the very conspiracy she was trying to quell, so she yielded the principle at issue and tacitly accepted our theory of expatriation.[3] All citizens of the United States, native or naturalized, not too deeply implicated in the uprising of the conspiracy, were liberated upon proper evidence of their citizenship.[4] Even the death sentences of those found guilty of treason were mitigated[5] upon the plea of our Department of State that the offenses were political in their nature and that executions would but arouse anew American sympathy for the defeated cause.[6]

[1] *Diplomatic Correspondence*, 1866, Vol. I, p. 69.

[2] *Diplomatic Correspondence*, 1867, Vol. I, p. 144.

[3] *Diplomatic Correspondence*, 1866, Vol. I, pp. 119, 136; 1867, Vol. I p. 132. For details, *ibid.*, 1867, Vol. I, pp. 94, 97, 98, 99, 129, 131, 139, 144, 152, 155, 156, 189, 1200; 1868, Vol. I, pp. 21, 31, 136, 174, 191.

[4] By November 22, 1867, but ten persons claiming to be citizens of the United States were still held in Irish prisons (*Diplomatic Correspondence*, 1868, Vol. I, p. 21).

[5] *Diplomatic Correspondence*, 1867, Vol. I, p. 64. [6] *Digest of International Law*, Vol. VI, p. 329.

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The first formal step that Secretary Seward took in using the Fenian Brotherhood as a means of making Great Britain come to terms upon the Alabama and other questions, later settled in the Treaty of Washington, was on March 20, 1865. The British government had sent a note to Seward denouncing our attitude toward the Fenian conspiracy and requesting particularly that the United States should no longer allow her officials and, as well, the officials of the states to attend meetings of the Brotherhood. Seward on the above date, replied to the note.[1] He gave the reasons why the United States could not interfere with the Brotherhood and declared that there had not yet arisen a case that offered sufficient reasons for interfering with their meetings. "I may properly add," he sagaciously continued, "that this government has no sufficient grounds to apprehend that any such case will occur unless renewed and systematic aggressions from the British ports and provinces should defeat all the efforts of this government to maintain and preserve peace with Great Britain."

On June 11, 1866, five days after President Johnson's warning proclamation, the House referred[2] to the proper committee a proposition for the repeal of our neutrality laws for the avowed purpose[3] of letting the Fenians get at the Canadians and the British Empire generally. On July 23 the House passed a resolution[4] requesting the Committee on Foreign Affairs to inquire into the expediency of reporting a bill applying the same regulations toward belligerents that the government of Great Britain had applied to the late Confederacy. The bill was reported and passed with entire unanimity. The Senate did not concur and so the bill was lost. Yet the action of the House gave great impetus to the preparations the Fenians were then making for sending money, men and arms to Ireland. President Johnson's annual message[5] (December, 1866) spoke of the Fenian organization as one "purely political" in its nature and gave no hint that measures would be taken to prevent its members from breaking our neutrality laws again or to prevent their giving such aid to Ireland as they chose.

[1] *Diplomatic Correspondence*, 1865, Vol. II, p. 103.
[2] *House Journal*, 1st sess., 39th Cong.
[3] *The Nation*, June 15, 1866, p. 760.
[4] *House Journal*, 1st sess., 39th Cong., p. 1091.
[5] RICHARDSON, *Messages of the Presidents*, Vol. VI, p. 458.

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Much soreness and irritation was engendered in England by this attitude of the United States toward the Fenians and there was great dissatisfaction, so Adams reported,[1] with what looked like mere sluggishness on the part of the British government in not making representations and remonstrances to the American government regarding their attitude of passive assistance to the Fenian Brotherhood at a time when the Brotherhood was pouring both men and money into the Emerald Isle. But the British authorities were fully conscious of the awkwardness of making such remonstrances in the face of all that had happened during the Civil War, so satisfied themselves with a note of hearty thanks for the vigorous way in which the United States suppressed the invasion into Canada.[2]

But it was during the awful turmoil in Ireland of March, 1867, that the United States authorities revealed most clearly their determination to foster the Fenian conspiracy until England should come to terms on the vexed Alabama affair. It was on March 27 that the House passed the four resolutions spoken of above, all of which were framed to reveal the peaceful attitude of the House toward the Fenians and its belligerent attitude toward Great Britain. On the next day Seward wrote Adams[3] that there "are unmistakable indications that the sentiments which controlled the action of the House of Representatives are now gaining favor in the other branch of Congress." He referred to Lord Stanley's proposition to arbitrate the Alabama claims, technical definitions being first agreed upon, and averred that in that form his offer could not be accepted. With this assertion he turns significantly to the discussion of affairs in Ireland, saying in part:

> I assume it to be possible that somewhere and at some time a seditious party in Ireland may proclaim an organized insurrection with a show of delegated authority from some portions of the Irish people. Such a proceeding is intensely expected by many citizens of the United States. That expectation excites a profound sympathy among adopted citizens of Irish birth and their descendants. It is equally manifest that the sympathy of the whole American people goes with such movements, for the reason that there is a habitual jealousy of British proximity across our northern border, and especially for the reason that this nation indulges a profound sense that it sustained great injury from the sympathy extended in Great Britain to the rebels during our Civil War.

[1] *Diplomatic Correspondence*, 1868, Vol. I, p. 74.
[2] *Correspondence Relating to the Fenian Invasion*, p. 144.
[3] *Diplomatic Correspondence*, 1867, Vol. I, p. 75.

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In January, 1868, after referring to the Fenian disturbances of the latter part of 1867 Seward, in a note to Adams,[1] said:

> It is plainly to be observed that the sympathies of the people of the United States are every day more profoundly moved in behalf of Ireland. I have continually endeavored to impress upon the British government the importance of eliminating from the so-called Fenian excitement, as far as possible, certain legitimate causes of irritation and jealousy between the people of the United States and the people of Great Britain. I have had less success than I had hoped, and less, I am sure, than would have been conducive to the interests of both countries. . . . .The people are appealing to the government throughout the whole country. . . . . Perhaps after this popular protest shall have found earnest expression in both houses of Congress, British statesmen may perceive that a restoration of cordial and friendly relations between the two countries is impossible while causes of irritation to which I have referred are allowed to endure.

These representations of Seward's Adams conveyed to the British government. They were just as self-evident to the British officials as to Seward himself. Therefore, Great Britain not only did not refuse to give consideration to our claims but, because of the continuance of the Fenian turmoil, consented to arbitrate. Finally in 1870 the threat of a general European war made Great Britain desirous of having us accept the same principles of neutrality, in case of such a war, as we had demanded that Great Britain enforce during our Civil War, and so she laid down the stringent "three rules" by which the Alabama claims should be arbitrated. Applying these rules, the Geneva Tribunal made us the $15,000,000 award. Indeed, the whole treaty of Washington was, in a measure, the result of this desire on the part of the British to do away with the American support of Irish revolutions. The British commissioner to the Treaty of Washington submitted the claims of the people of Canada against the United States government for loss in life, property, and expenditure occasioned by the invasions into Canada.[2] The United State commissioners, however, refused[3] to consider these claims on two grounds: (1) that the preliminary negotiations had said nothing about them, and (2) that the United States had used due diligence in suppressing the invasion, citing as evidence the contemporary testimony of the Canadian and English authorities themselves.

[1] *Diplomatic Correspondence*, 1868, Vol. I, p. 142.

[2] MOORE, *International Relations*, Vol. I, pp. 686, 687.

[3] MOORE, *International Arbitrations*, Vol. I, p. 687.

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In summary, then, we may say that the Fenian Brotherhood was made possible by the fact that the great majority of the Irish in the United States at the time were unassimilated and still insular in their interests. Without the impetus given to the Brotherhood by the Civil War the movement never would have attained international importance. The conspiracies of the Brotherhood were against a foreign power with which our relations were such that we could use the Brotherhood as a menace if the power did not come to our terms, and so the activities of the Brotherhood redounded to the advantage of our nation. Yet there is something of a warning, after all, in the movement, for the outcome of other such organizations—the work of unassimilated foreigners in the United States—cannot always be so fortuitous.

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# THE ELECTROCHEMISTRY OF THE SOLUTION OF GOLD IN POTASSIUM CYANIDE

By John B. Ekeley and Arthur L. Tatum

In 1893, McLaurin[1] proved definitely that gold will dissolve in potassium cyanide solution when there is oxygen present, but that, if no oxygen is contained in the cyanide solution, the gold remains unacted upon. From pure hydrocyanic acid and potassium hydroxide dissolved in water freed from air by long boiling, McLaurin prepared a solution of potassium cyanide. A Dumas bulb was partly filled with this solution, a strip of pure gold was placed in the neck of the bulb, and, while the solution was boiling, the neck was sealed. The gold was allowed to remain in the solution for 24 hours, the gold losing .0002 grm. The gold was then allowed to remain in contact with the same solution in the presence of air for 24 hours, during which time it lost .0083 grm. This is the best experimental evidence that we have that gold requires oxygen for its solution in potassium cyanide.

Although other investigators took up the study of the solubility of gold in potassium cyanide, little of any great value in a theoretical way was brought forward until Christy[2] took the subject up from an electrochemical standpoint, his work being published in 1902.

Christy made use of the $Au/KCN/Hg_2Cl_2/Hg$ couple, measuring the electromotive force and finding that the positive current flows in the cell from the gold electrode to the mercury, gold going into solution and mercury being deposited. He then suggests that, should an oxygen electrode be substituted for the calomel electrode, the gold would go into solution in the cyanide and the platinum would receive the same electrical charge that he found in the case of the mercury. In support of this he performed the following experiment. A strip of gold was suspended in a solution of potassium cyanide that had been saturated with oxygen. A second strip of gold was suspended in a similar solution freed from oxygen by boiling and subsequently protected by a layer

[1] *Journal of the Chemical Society of London*, Vol. LXIII, p. 727.

[2] *Electrochemische Zeitschrift*, Vol. XVIII, p. 227.



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of oil. The two solutions were connected by means of a liquid bridge, and the two gold strips by means of a wire and galvanometer. Gold dissolved in the oxygen-free solution and a current was shown by the galvanometer to be flowing in the solutions from the oxygen-free solution to that containing the dissolved oxygen.

The following explanation of the phenomenon has occurred to us. Christy's cell is analogous to the simple cell constructed in the same manner by substituting zinc in sodium sulphate for gold in oxygen-free cyanide and copper in sulphuric acid for gold in oxygenated cyanide. Here the current flows in the solutions from the zinc to the copper, zinc dissolving in one solution and hydrogen being liberated on the copper in the other solution. The zinc dissolves in the absence of acid just as in Christy's cell the gold dissolves in the absence of oxygen. In the zinc-copper cell, the solution pressure of the zinc drives zinc ions into the solution, the hydrogen ions in the other solution being thus forced out, giving their charges to the copper with the production of a current outside the cell from copper to zinc. In Christy's cell, the gold, on account of its solution pressure, sends gold ions into the solution. Hydrogen ions in the oxygenated cyanide vessel (due to the slight ionization of water into $\dot{H}$ ions and $\acute{O}H$ ions) tend to be forced out just as in the zinc-copper cell, but this does not occur. The dissolved oxygen sends by virtue of its solution pressure, oxygen ions, $\ddot{O}$, into the solution. These $\ddot{O}$ ions with the $\dot{H}$ ions form $\acute{O}H$ ions, so that the cell acts like a bichromate cell, or any other oxidation cell, instead of like a simple zinc-copper couple. The $\acute{O}H$ ions thus left in the solution form with the $\dot{K}$ ions dissociated KOH.

In view of the above considerations, it seemed interesting to us to set up a Au/KCN/O-Pt couple. As expected, gold dissolved rapidly in the cyanide, the rate varying with the concentration of the cyanide, and the concentration of the oxygen in the oxygen electrode, the current passing in the couple from the gold to the oxygen. Solubility determinations were made, first, with the external circuit closed, and secondly, with the external circuit broken. Exact solubility determinations are needless and impossible on account of the difficulty of excluding air from the cyanide, and of the variability in the potential of the oxygen electrode.

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If it were possible to supply oxygen to the platinized platinum at a high enough speed and at the same time exclude all air from the cyanide (other things being equal, such as physical condition of the gold, etc.), the solubility would undoubtedly be directly proportional to the current, according to Faraday's law. As a matter of fact, the physical condition of the gold varying and causing a varying occlusion of oxygen on its part, the oxygen held in solution by the cyanide, and the varying amount of oxygen occluded by the platinized platinum undoubtedly cause the gold to dissolve at a rate not proportional to the current flowing through the cell. Hence the solubilities indicated in the following table are not to be considered more than fair approximations.

| Strength of KCN | Time | Gold Dissolved | |
|---|---|---|---|
| .05 per cent. | 2 hrs. | .0219 grm. | Circuit closed |
| .05 per cent. | 2 hrs. | .0036 grm. | Circuit open |
| .10 per cent. | 2 hrs. | .0307 grm. | Circuit closed |
| .10 per cent. | 2 hrs. | .0055 grm. | Circuit open |
| .15 per cent. | 1 hr. | .0193 grm. | Circuit closed |
| .15 per cent. | 1 hr. | .0033 grm. | Circuit open |

We also measured the potentials of gold in varying concentrations of cyanide against the oxygen electrode, with results which agree with the measurements of Christy and others made against the calomel electrode.

| Strength of KCN | Gold potential. |
|---|---|
| .10 per cent. | .12 volt |
| .15 per cent. | .14 volt |
| .65 per cent. | .21 volt |
| .80 per cent. | .22 volt |
| 1.00 per cent. | .29 volt |

The equation for the solubility of gold in potassium cyanide, often called Elsner's equation, is

$$4Au+8KCN+2H_2O+O_2=4KAu(CN)_2+4KOH\,.$$

The gold dissolves on account of the formation of innumerable short-circuited gold-oxygen cells. The gold sends $4\dot{A}u$ ions into the solution by virtue of its solution pressure, and at the same time the dissolved oxygen sends $2\ddot{O}$ ions into the solution by virtue of its solution pressure. The $4\dot{A}u$ ions react with $8\acute{C}N$ ions of the dissociated KCN forming $4Au(\acute{C}N)_2$ ions, and the $2\ddot{O}$ ions react with $2\dot{H}$ ions (present from the

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dissociation of $2H_2O$ molecules into $2\dot{H}$ and $2\acute{O}H$), forming $2\acute{O}H$ ions. Thus the ions present before solution of the gold are

$$4\dot{Au}+8\dot{K}+8\acute{C}N+2\dot{H}+2\acute{O}H+2\acute{\acute{O}}$$

and after the reaction

$$8\dot{K}+4\dot{Au}(\acute{C}N)_2+4\acute{O}H\,,$$

or, written in the form of an equation,

$$4\dot{Au}+8\dot{K}+8\acute{C}N+2\dot{H}+2\acute{O}H+2\acute{\acute{O}}=8\dot{K}+4\dot{Au}(\acute{C}N)_2+4\acute{O}H\,.$$

Oxygen need not necessarily be the carrier of the four negative charges required. Any substance capable of furnishing these charges would cause gold to dissolve in potassium cyanide, or any mechanical means of furnishing these four charges would have the same effect. In this latter case, the equation would be

$$2\dot{Au}+4\dot{K}+4\acute{C}N+2\dot{H}+2\acute{O}H=4\dot{K}+2\dot{Au}(\acute{C}N)_2+2\acute{O}H+H_2\,,$$

and gaseous hydrogen would be liberated from the cyanide solution as the gold dissolved.

Cyanogen bromide added to a potassium cyanide solution is a very effective gold solvent. The commonly accepted reaction is

$$Au_2+3KCN+BrCN=2KAu(CN)_2+KBr.$$

Considered electrochemically the reaction is as follows: The solution pressure of the gold sends $2\dot{Au}$ ions into the solution, while the solution pressure of the cyanogen bromide sends a $\acute{Br}$ ion and a $\acute{C}N$ ion into the solution. The $2\dot{Au}$ ions react with the $4\acute{C}N$ ions forming $2Au'(CN)_2$ ions, so that the equation would be written

$$2\dot{Au}+3\dot{K}+3\acute{C}N+\acute{Br}+\acute{C}N=2\dot{K}+2\dot{Au}(\acute{C}N)_2+\dot{K}+\acute{Br}.$$

It should therefore be possible to set up a cell in which gold and solid cyanogen bromide are the electrodes and potassium cyanide the electrolyte. The current would flow in the cell from the gold to the cyanogen bromide, both being consumed, just as in the gold-oxygen cell the current flows in the cell from the gold to the oxygen, both being consumed.

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# AN ANNOTATED LIST OF THE BIRDS OF BOULDER COUNTY, COLORADO

By Junius Henderson

Boulder County is a well-settled county, compared with some others of the state, and in its midst is situated the University of Colorado, with its rapidly increasing student body, therefore it appears to deserve a carefully prepared bird list. The present paper gives the results of seventeen years' study of the county's avifauna and the literature bearing thereon. Not being an ornithologist, these notes contain only such information as the writer has been able to gather while in the field engaged in paleontological and conchological investigation, supplemented by access to the notes, published and unpublished, of others.

Boulder County is approximately twenty-four miles wide (north-south) and about 32 miles long (east-west). The western edge follows the irregular crest of the Continental Divide, the highest point being Long's Peak, in the extreme northwest corner, 14,271 feet above the sea according to the "Hayden Survey," more recent surveys slightly, but not materially, changing those figures; the lowest point, near the eastern boundary, being about 5,000 feet. There is thus presented a difference of about 9,000 feet between extremes of altitude, with corresponding differences in temperature, humidity, atmospheric density, vegetation, etc. Nearly the western two-thirds of the county is mountainous, the remainder forming a portion of the western edge of the Central Great Plains, locally called "the valley" to distinguish it from the mountainous area. Both areas present a great variety of conditions aside from mere differences in altitude, from which a varied avifauna would be expected. It is therefore an ideal field for the student of ornithology.

The formerly semi-arid plains area has been, to a great extent, transformed into irrigated and cultivated fields, though tracts of considerable size above the convenient reach of ditches on the divides between streams still remain dry, treeless, shrubless prairie. Four principal streams and several minor ones, issuing from the mountain



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canyons, flow in a general easterly and northeasterly direction out to the plains, in valleys not well marked, nearly all uniting with the St. Vrain before reaching the county line.

In the valleys and throughout the irrigated areas there are numerous trees and shrubs, many of them exotic. Ponds and lakes abound, some natural, others artificial. To the westward the plains pass abruptly into the foothills, from which the mountains rise less abruptly to the crest of the range. The mountain area is an ancient granite plateau[1] deeply dissected by canyons cut by the streams flowing outward to the plains, the outlines being much more rounded than where similar gorges are cut through horizontal stratified rocks.

The mountains are covered by coniferous forests, in some places quite dense, coming down to the bottoms of the canyons, where they are interspersed with mountain maple, birch, alder, willow, narrow-leafed cottonwood, aspen and other deciduous trees and shrubs.[2] The cottonwoods and aspens are the only deciduous trees reaching much size and only the latter are found up the mountain slopes and on the divides between canyons. The coniferous forests are irregular, with many open, treeless, meadow or park-like areas.

Glacial lakes interrupt the courses of some of the streams above 10,000 feet. Lakes and ponds, probably mostly of different origin, abound on some of the divides down to 8,000 feet or lower. Above timberline, which varies from 10,500 to 11,500 feet, are open divides and rocky gorges, with perennial banks of snow and ice in places favorable for their preservation, including one well-developed glacier. Vegetation of some kind, with attendant insects, extends to the rocky, serrated crest of the range, affording food for birds even on the highest points. Consequently some species are found on the range which are never seen in the valley, while some of the valley species do not reach the range.

Owing to the differences in altitude, temperature, etc., the study of bird migrations is more complicated than in more level regions, there being a sort of vertical migration as well as the regular northward and

[1] FENNEMAN, N. M., "Geology of the Boulder District, Colorado," *U. S. Geol. Surv., Bull. No. 265*, 1905.

[2] YOUNG, ROBERT T., "Forest Formations of Boulder County," *Botanical Gazette*, Vol. XLVI, pp. 321-352, 1907. RAMALEY, FRANCIS, "Woody Plants of Boulder County," *University of Colorado Studies*, Vol. V, pp. 47–63, 1907.

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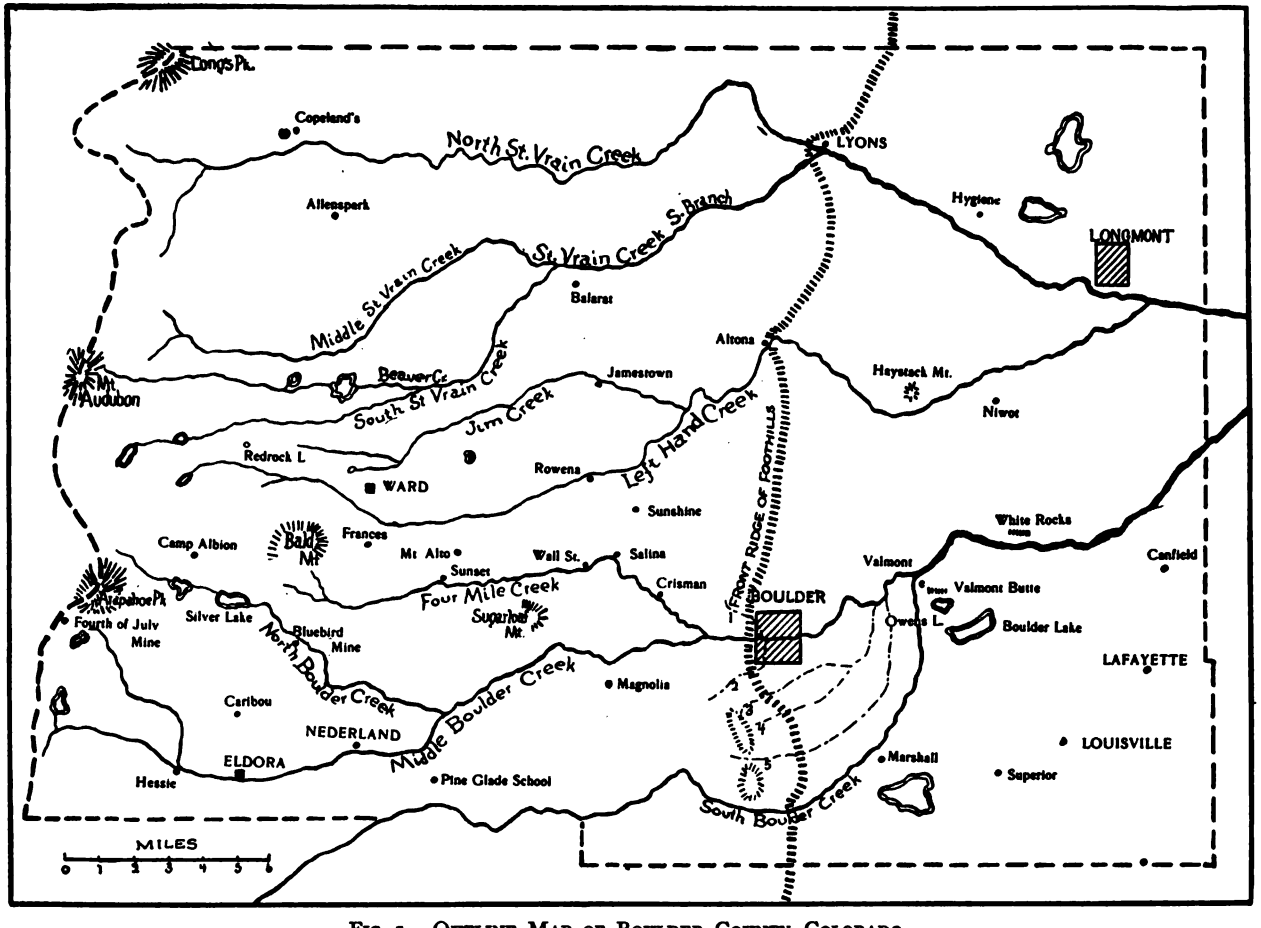


FIG. 1.—OUTLINE MAP OF BOULDER COUNTY, COLORADO

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southward movements.[1] Valuable notes on vertical migration a few miles south of this county were made by Mr. T. M. Tripp.[2]

It is sought herein to list all species hitherto reported from Boulder County. The species which remain the year round are designated "resident," those which simply pass through in their spring and fall migrations are termed "migrants," though in many cases it is possible that a few may remain through winter or summer unnoticed. The terms "summer residents" and "winter residents" are self-explanatory, both summer residents and residents of course nesting here.

In the preparation of this list of 216 species (exclusive of those bracketed to indicate doubt as to their occurrence, though quite a number of those records are probably correct) the writer has consulted, in addition to his own notes and the publications mentioned in the bibliography herewith, manuscript notes and verbal communications furnished by the following persons: Denis Gale, James Cowie, C. W. Rowland, H. G. Smith, Wm. A. Sprague, L. C. Bragg, J. R. Brackett, A. H. Felger, Harvey Markman, F. M. Dille, Walter Blanchard, Robt. B. Rockwell, Alex Mackenzie. The collections in the University museum, especially the Gale nests and eggs, and some specimens in the cabinets of the State Historical and Natural History Society in the State Capitol, at Denver, have also furnished valuable information. Probably 30 or more other species occur here which have not been noted. The species are named and numbered according to the check-list of the American Ornithologists' Union and supplements thereto down to the time of completion of the manuscript in December, 1908.

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## SYSTEMATIC LIST, ANNOTATED

4. **Colymbus nigricollis californicus**—American Eared Grebe.

Summer resident about the plains lakes, not common. One in University collection. Gale found its nest in or near the county.

6. **Podilymbus podiceps**—Pied-billed Grebe.

Common in migration. Gale found one nest. A nestling collected by Bragg in 1904 is in University cabinets.

7. **Gavia immer**—Loon.

I saw one on the plains, May 7, 1905. One in University cabinets taken by L. C. Bragg in 1901, no date. One in possession of F. M. Marshardt taken near Boulder, March 10, 1908.

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[9. *Gavia arctica*—Black-throated Loon.
The former record of this species too doubtful to be retained.]

37. **Stercorarius parasiticus**—Parasitic Jaeger.
Mrs. Maxwell's December specimen the only Boulder County record.

40. **Rissa tridactyla**—Kittiwake.
Mrs. Maxwell's December specimen the only Boulder County record.

54. **Larus delawarensis**—Ring-billed Gull.
Common on the plains in migration.

62. **Xema sabinii**—Sabine Gull.
Recorded from here by Cooke, and six reported on the plains during migration season by Cowie, one of which he secured for the University.

77. **Hydrochelidon nigra surinamensis**—Black Tern.
One in University collected by Bragg in 1904, on the plains.

125. **Pelecanus erythrorhynchos.**—American White Pelecan.
Hunters say it has been occasionally taken on the plains in migration, but have no dates. Doubtless of rare occurence now.

130. **Mergus serrator**—Red-breasted Merganser.
Reported as a migrant by Rowland.

131. **Lophodytes cucullatus**—Hooded Merganser.
I have seen but one taken here.

132. **Anas platyrhynchos**—Mallard.
Common on plains in migration and winters here (Cowie). Rockwell found it common west of Longmont, December 30–31, 1906, and January 1, 1907. Probably a number of our ducks nest here sparingly, but we cannot assume this.

135. **Chaulelasmus streperus**—Gadwall.
Common on plains in migration. Rockwell found this and Nos. 137, 140, 141, 142, 149, in pairs near Niwot, May 20 and 28, 1904, so they likely nested there.

137. **Mareca americana**—Baldpate.
Common on plains in migration. See remarks on No. 135.

139. **Nettion carolinensis**—Green-winged Teal.
Common on plains in migration, and some nest here (Cowie).

140. **Querquedula discors**—Blue-winged Teal.
Common on plains in migration, and some nest here (Cowie). See remarks on No. 135.

141. **Querquedula cyanoptera**—Cinnamon Teal.
Reported on plains in migration by Rowland, Cowie and others. See remarks on No. 135.

142. **Spatula clypeata**—Shoveller.
Common on plains in migration. See remarks on No. 135.

143. **Dafila acuta**—Pintail.
Common on plains in migration. Hunters reported them in early January, 1909.

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144. **Aix sponsa**—Wood Duck.

Very rare. Mr. Cowie and Bert Werley took three near Boulder in 1904, our only definite records.

146. **Marila americana**—Redhead.

Common on plains in migration.

147. **Marila vallisneria**—Canvasback.

On plains in migration, not common.

[148. *Marila marila*—American Scaup Duck.

Felger's specimen recorded by this writer is believed to have been taken just over the county line.]

149. **Marila affinis**—Lesser Scaup Duck.

Rare migrant reported by Felger as collected at Longmont by L. C. Fipps, October 25, 1903. See remarks on No. 135. I have examined but one specimen from the county.

[150. *Marila collaris*—Ring-necked Duck.

Eliminated because Rowland's record not definite enough and Felger's found to be just over the county line.]

151. **Clangula clangula americana**—American Goldeneye.

Rare migrant on plains. Cowie says hunters get a few every year. One in University collection taken on Beasley Lake, February 17, 1908.

152. **Clangula islandica**—Barrow Goldeneye.

Summer resident or perhaps resident, passing well up into the mountains. Gale found young birds on upper St. Vrain, July 19, 1886.

153. **Charitonetta albeola**—Bufflehead.

Common on plains in migration.

154. **Harelda hyemalis**—Old-Squaw.

Rare migrant reported by Rowland. H. G. Smith records one taken by Judge Park at Longmont in 1903. As Longmont is near the county line, the lake where this was taken may be in Weld County.

[165. *Oidemia deglandi*—White-winged Scoter.

Felger's specimen recorded by this writer was taken just over the line at Calkins Lake, so it is eliminated.]

167. **Erismatura jamaicensis**—Ruddy Duck.

Reported by Rowland and Cowie as frequent in migration. One taken by Felger at Lyons, March 24, 1900.

[169. *Chen hyperborea*—Lesser Snow Goose.

Record too uncertain to retain.]

[169*a*. *Chen hyperborea nivalis*—Greater Snow Goose.

Record too uncertain to retain.]

172. **Branta canadensis**—Canada Goose.

Common on plains in migration. Found nesting west of Niwot by Cooke in 1897.

180. **Olor columbianus**—Whistling Swan.

Migrant, not common. Two in University Museum and three more were brought in for identification by local hunters in spring of 1907.

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190. **Botaurus lentiginosus**—American Bittern.
Summer resident on plains, not common.

194. **Ardea herodias**—Great Blue Heron.
Common summer resident on the plains and occasionally seen in the foothills. The St. Vrain colony near Hygiene is well known.

197. **Egretta candidissima**—Snowy Heron.
Rare migrant on plains. One reported by Hersey in 1876. Two collected in spring of 1908, one of which is in University Museum.

202. **Nycticorax nycticorax naevis**—Black-crowned Night Heron.
Summer resident, not common. Two in University collection.

212. **Rallus virginianus**—Virginia Rail.
Summer resident on plains, not uncommon. Two specimens in University collection and one nest with 11 eggs, collected by Bragg northeast of Boulder on June 7, 1904. Rockwell collected a nest and eggs at Budd reservoir, May 28, 1904.

214. **Porzana carolina**—Sora.
Summer resident, not uncommon. Felger found one dead on Arapahoe Glacier, altitude about 12,000 feet, in 1904. Gale found a pair at 9,500 feet apparently with nest, on June 28, 1889, but did not find nest. Nest collected by him in University collection dated May 25, 1880, but no locality given. One with 14 eggs collected by Bragg northeast of Boulder on June 7, 1904, in University cabinets.

221. **Fulica americana**—American Coot.
Common summer resident on plains, abundant in migration.

223. **Lobipes lobatus**—Northern Phalarope.
Occasional on plains in migration.

224. **Steganopus tricolor**—Wilson Phalarope.
Common in migration on plains, less common as a summer resident. Gale found its eggs (from two to four per set) in May and June.

225. **Recurvirostra americana**—American Avocet.
On plains in migration, not common. A pair observed by Rockwell at Twin Lakes, near Niwot, May 20, 1904, which indicates nesting.

[226. *Himantopus mexicanus*—Black-necked Stilt.
Record too doubtful to be retained.]

228. **Philohela minor**—American Woodcock.
Rare summer resident on plains. One seen near Boulder in 1887 by Mr. John Bentley (Cooke and H. G. Smith), one seen by the writer one mile east of Boulder in 1905, on May 24 and 30. Reported also by Rowland.

230. **Gallinago delicata**—Wilson Snipe.
Common on plains in migration, rare winter resident. In February, 1904, the writer noted it frequently on Boulder Creek just outside of the city limits. Gale noted it only as a winter visitor on the plains. Nesting in fair numbers northeast of Boulder for past five years (Dille).

[233. *Micropalama himantopus*—Stilt Sandpiper.
Record too uncertain to be retained.]

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240. **Pisobia fuscicollis**—White-rumped Sandpiper.
Reported as migrant on plains by Rowland.

254. **Totanus melanoleucus**—Greater Yellow-legs.
Common on plains in migration.

255. **Totanus flavipes**—Yellow-legs.
Common on plains in migration.

256. **Helodramus solitarius**—Solitary Sandpiper.
One taken by Felger at Pennsylvania Lake, altitude 8,500 feet, August 27, 1903.

263. **Actitis macularia**—Spotted Sandpiper.
Common summer resident, reaching 10,000 feet by the last of May according to Gale, who places its nesting range at from 8,000 to 10,000 feet, though likely it nests sparingly at lower altitudes. Six nests in Gale collection, all taken in June, running two, four and five eggs in a set.

264. **Numenius americanus**—Long-billed Curlew.
Gale noted it in his manuscript list of summer residents, both for plains and mountains, but without definite records. Probably does not get far back of the foothills. He collected several sets of eggs, but his notes omit localities. Cowie says it is not infrequent on the plains lakes.

273. **Oxyechus vociferus**—Killdeer.
Abundant summer resident on plains, less abundant in mountains. Earliest spring records I have for the county are March 19 (Gale), March 5 (Rockwell) and March 29 (C. Juday). H. G. Smith says he saw three just east of Boulder on December 31, 1904.

[281. *Podasocys montanus*—Mountain Plover.
Gale notes young birds "on the dry plains," sent a skin to Washington and discusses nesting habits, but does not make it clear whether his observations occurred in the county or not.]

289. **Colinus virginianus**—Bob-white.
Recorded on plains in 1889 by Gale. As some have been introduced it is difficult to ascertain whether it was a native species here. Common now in favorable localities.

297. **Dendragapus obscurus**—Dusky Grouse.
Resident in mountains, much less common than formerly. Nests from higher foothills to about timberline. A slight vertical migration occurs among the birds of the higher region in severe winter weather.

304. **Lagopus leucurus**—White-tailed Ptarmigan.
A bird of the alpine region, nesting above timberline, but said to come "as low as 8,500 feet and quite seven miles from the range" in winter (Gale). Not common except in isolated places.

[308*b*. *Pediœcetes phasianellus campestris*—Prairie Sharp-tailed Grouse.
Have no definite record for the county, but Gale inserts it in a list of birds wintering on the Boulder County plains, and discusses its nesting habits without locality. Probably formerly occurred here, but not now found.]

312. **Columba fasciata**—Band-tailed Pigeon.
Noted in a gulch near Gold Hill by Gale on the following dates: June 8, 1887; June 8, 1888; June 9, 1889; June 2, 1890. Always in the same place and no other records.

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316. **Zenaidura macroura carolinensis**—Mourning Dove.

Abundant summer resident from the plains to 8,000 feet, less common to 10,000 feet. Arrives in March or April and a few remain late in the fall.

325. **Cathartes aura septentrionalis**—Vulture.

No longer common in most of the county. One taken near Boulder three years ago in University Museum. Gale noted them near Lyons in 1888 and found them nesting in same trees with great blue herons. Markman records them at same place in June, 1907, and on October 2, 1908, I saw several.

331. **Circus hudsonius**—Marsh Hawk.

Common summer resident of plains and mountains; less common in winter on plains, with no winter mountain records.

332. **Accipiter velox**—Sharp-shinned Hawk.

Resident of valley and mountains.

333. **Accipiter cooperii**—Cooper Hawk.

Common resident of plains and mountains. Gale found it nesting near head of Left Hand Creek.

334. **Astur atricapillus**—American Goshawk.

Have seen but two, both killed in 1908, one of which is in University Museum. Reported also by Sprague in his notes many years ago. H. G. Smith says he saw one in a taxidermist's workshop, which was killed at Sugar Loaf, February 21, 1888.

337*b*. **Buteo borealis calurus**—Western Red-tail.

Common summer resident of plains and mountains, less common in winter.

342. **Buteo swainsoni**—Swainson Hawk.

Common resident of plains, less common in mountains. Gale took several sets of eggs.

348. **Archibuteo ferrugineus**—Ferruginous Rough-leg.

Noted in Gale's Boulder County list as wintering on plains. One from near Boulder in University collection.

349. **Aquila chrysaëtos**—Golden Eagle.

Resident, not common.

352. **Haliæetus leucocephalus**—Bald Eagle.

I have seen but one and one reported by Blanchard.

355. **Falco mexicanus**—Prairie Falcon.

One reported by Blanchard, and Gale twice found it nesting on the St. Vrain.

356*a*. **Falco peregrinus anatum**—Duck Hawk.

One taken by Harry Holland, September 11, 1898, labeled Longmont, is in cabinets at State Capitol. Another in same collection, taken by B. Hayward, labeled Longmont, may be from Calkins Lake. Gale found it nesting just north of the county line.

357*b*. **Falco columbarius richardsoni**—Richardson Merlin.

One taken near Silver Lake, 10,000 feet, in September. Winters on plains and in mountains, according to Gale, who took one near Boulder, January 5, 1885, now in Felger's cabinets.

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360. **Falco sparverius**—American Sparrow Hawk.

Our most common summer hawk from plains to timberline, a few sometimes remaining through the winter.

[365. *Aluco pratincola*—American Barn Owl.

The evidence does not warrant the retention of this record.]

366. **Asio wilsonianus**—American Long-eared Owl.

Common resident of plains and mountains. Eleven sets of eggs in the Gale collection in University Museum.

367. **Asio flammeus**—Short-eared Owl.

One in University collection taken by Bragg at Boulder in 1903. Noted by Rockwell near Niwot, March 26, 1904, and at Longmont, December 30, 1906.

368. **Strix varia**—Barred Owl.

Gale noted the species on plains near Boulder in 1886.

372. **Glaux acadicus**—Saw-whet Owl.

Found by Gale nesting up to 8,500 feet. He recorded it at various points in 1889 and 1890. Sprague also reported it from the mountains.

373*e*. **Otus asio maxwelliæ**—Rocky Mountain Screech Owl.

One of our most common owls, named in honor of Mrs. Maxwell, who prepared the collection of birds and mammals of Colorado for the Centennial Exposition at Philadelphia. Gale reported it nesting both in the lower mountain region and on the plains. Of 14 nests in the University cabinets collected by him, unfortunately the altitude and locality are missing from all the labels. The eggs run 4, 5 and 6 to the set and the dates run from April 13 to May 19. Cooke reports it at Lamb's ranch in Estes Park, 9,000 feet, which is near the north line of Boulder County.

374. **Otus flammeola**—Flammulated Screech Owl.

Our rarest owl. Of the first 14 specimens taken in Colorado (being the first 23 for the United States), 7 were taken in Boulder County. The Sprague specimen is now the property of Hon. R. H. Whiteley, of Boulder. Apparently a bird of the mountains here. No actual nesting records, but no reason to doubt that it nests in the county. Dille records two nests from Estes Park, just north of Boulder County.

375*a*. **Bubo virginianus pallescens**—Western Horned Owl.

Our largest owl, rather common resident of plains and mountains.

376. **Nyctea nyctea**—Snowy Owl.

Very rare winter visitor.

378. **Speotyto cunicularia hypogæa**—Burrowing Owl.

Our most abundant owl on the plains, perhaps less common in the winter. Have not seen it in the mountains. Gale found in its nests remains of small rodents and one shore lark.

379. **Glaucidium gnoma**—Pygmy Owl.

Rare resident of mountains and plains. Gale had at least two specimens (perhaps the two now in Felger's collection, taken near Boulder, altitude 7,500 feet, January 20, 1891), and in dissecting them found in one a mouse and in the other a mouse and a shrew. One collected by Bragg near Boulder is in the University cabinets.

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387*a*. **Coccyzus americanus occidentalis**—California Cuckoo.

One specimen collected by Bragg in 1904 is in the University cabinets.

390. **Ceryle alcyon**—Belted Kingfisher.

Summer resident of mountains and plains, formerly common, now not very common. In 1903–4 two remained along Boulder Creek all winter within the city limits of Boulder.

393*e*. **Dryobates villosus monticola**—Rocky Mountain Hairy Woodpecker.

Common resident in mountains. Have seen it in Boulder only in winter. This county is the type locality. Thirteen sets of eggs taken by Gale now in University cabinets were found at from 7,500 to 10,000 feet, the eggs numbering 4, 5 and 6 to the set. Three were from old pine stubs, the others from aspens from 2 to 25 feet from the ground.

394*b*. **Dryobates pubescens homorus**—Batchelder Woodpecker.

Resident of mountains. Have seen it in Boulder only in winter.

401*b*. **Picoides americanus dorsalis**—Alpine Three-toed Woodpecker.

Probably resident of mountains. Felger reported it in summer of 1903 and A. MacKenzie collected one on South Boulder Creek.

402*a*. **Sphyrapicus varius nuchalis**—Red-naped Sapsucker.

Common summer resident from foothills to timberline. Gale collection in University contains 45 sets of eggs, nearly all from live aspens, mostly taken at from 7,500 to 9,000 feet, all taken in June. The eggs vary greatly in size, many of the sets containing some eggs much smaller than the average.

404. **Sphyrapicus thyroideus**—Williamson Sapsucker.

Common summer resident from plains to timberline. In Gale collection are 57 sets of eggs, mostly taken at from 7,500 to 9,500 feet, from May 26 to June 27, in partly decayed aspen and conifer stumps.

406. **Melanerpes erythrocephalus**—Red-headed Woodpecker.

Common summer resident of mountains and plains, arriving late in May. Have seen them flocking with Lewis woodpeckers at 7,000 feet on September 1, as if preparing for migration. My latest autumn record at Boulder is October 23, 1904.

408. **Asyndesmus lewisi**—Lewis Woodpecker.

Common summer resident of lower mountain region, some remaining through the winter. Gale's two nests were taken at 5,800 and 6,000 feet, respectively, in June. On migration see preceding species.

413. **Colaptes cafer collaris**—Red-shafted Flicker.

Resident on plains and summer resident up to timberline, nesting at least up to Gold Hill. Gale says winter resident of mountains also. Our most abundant woodpecker. Have not seen *C. auratus luteus* here, but a specimen taken by Bragg near Boulder, now in the University cabinets, appears to be hybrid, *C. collaris* × *C. luteus*, probably the form which has been described as *C. hybridus*. Tripp (per Coues, *Birds of the Northwest*, p. 295) says: "Mrs. Maxwell, of Boulder, informs me that a yellow-winged flicker has appeared in the groves that fringe the streams near that town within the last few years, and is gradually becoming more abundant. From her description I should suppose it to be *C. auratus* but probably it is some form of *C. hybridus*."

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418. **Phalænoptilus nuttallii**—Poor-will.

Summer resident. Gale noted it but twice, both times near Gold Hill in 1889. Reported by Blanchard in Boulder Canyon in 1903 and by Sprague at Magnolia in 1898.

420*a*. **Chordeilus virginianus henryi**—Western Nighthawk.

Abundant summer resident from plains to 8,000 feet, common up to 10,000 feet or higher. Gale found it nesting up to 9,500 feet. Have seen it in Boulder as late as September 26, in 1905. On August 24, 1907, I counted over 50 in a flock flying southwestward over Flagstaff Mt., at Boulder. A few of these useful birds nest on flat roofs of Boulder business houses.

[422. *Cypseloides niger borealis*—Black Swift.

Gale includes this in his manuscript list of Boulder County birds, but nowhere in his notes mentions actually taking or even seeing it. Therefore, as it is a species of southwestern Colorado, the record cannot be safely accepted without further information.]

425. **Aëronautes melanoleucus**—White-throated Swift.

Summer resident of foothills and mountains, not common. Reported by Blanchard and found nesting several times by Gale, a pair taken by the latter in Left Hand Gulch, June 30, 1886, being in Felger's cabinets. Minot says rare about Boulder.

[429. *Trochilus alexandri*—Black-chinned Hummingbird.

The remarks on the black swift apply also to this species, except that it is found probably further north in the western part of the state.]

432. **Selasphorus platycercus**—Broad-tailed Hummingbird.

Common summer resident from edge of plains nearly to top of range. Most abundant at 9,000 to 10,000 feet.

433. **Selasphorus rufus**—Rufous Hummingbird.

One taken near Boulder by Gale and one in Mrs. Maxwell's collection with no locality label.

444. **Tyrannus tyrannus**—Kingbird.

Common summer resident of plains and foothills.

447. **Tyrannus verticalis**—Arkansas Kingbird.

Have seen but three at Boulder, May 30, 1906. Gale found them common in eastern part of county, nesting. The distribution of this species in northern Colorado is difficult to understand. It is abundant to the southeast and northeast of Boulder County.

448. **Tyrannus vociferans**—Cassin Kingbird.

One taken by A. Mackenzie on South Boulder Creek, the only one I have seen.

457. **Sayornis saya**—Say Phœbe.

Common summer resident of plains, nesting more sparingly up to about 8,000 feet. Have seen it at Boulder as late as September 15, in 1903.

459. **Nuttallornis borealis**—Olive-sided Flycatcher.

Summer resident of mountains, passing over plains in migration. Gale found it nesting at Ward, Gold Hill and Duck Lake, from 8,000 to 9,500 feet.

462. **Myiochanes richardsonii**—Western Wood Pewee.

Common summer resident of mountains, passing over plains in migration. Nests at from 5,500 to 10,000 feet, according to Gale.

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464. **Empidonax difficilis**—Western Flycatcher.

Common summer resident in mountains. Have seen it on the edge of the plains only in migration. Nine nests in Gale collection were taken at from 8,500 to, 10,000 feet and three of them were from mine shafts or tunnels, all in June and early July.

466. **Empidonax traillii**—Traill Flycatcher.

Common summer resident of plains and perhaps lower mountains. Five nests in Gale collection, all from the plains, and three contained a cowbird egg each. Felger has one bird taken by Gale at 5,500 feet, July 3, 1890.

[467. *Empidonax minimus*—Least Flycatcher.

Gale's notes mention one nest of this species, leaving it uncertain as to whether it was in the foothills or on the plains. Identity too doubtful for retention of record.]

468. **Empidonax hammondi**—Hammond Flycatcher.

Summer resident of mountains. Two nests were taken by Gale at 10,000 feet (Bendire).

469. **Empidonax wrightii**—Wright Flycatcher.

Common on plains, breeding in mountains, where Gale found it nesting up to 10,000 feet.

474*c*. **Otocoris alpestris leucolæma**—Desert Horned Lark.

Abundant resident on dry plains and in the mountains. Gale found it nesting on the open slopes above timber-line and on the dry plains, but at no intermediate point. In the severe winter of 1898–9 many thousands appeared on the streets of Boulder and were fed by the citizens. The nests, being on the ground, are often destroyed by heavy spring snows, whereupon they re-nest. I assign all our horned lark records to this species.

475. **Pica pica hudsonia**—American Magpie.

Common resident of plains and up to about 8,000 feet, less common to timberline.

478*b*. **Cyanocitta stelleri diademata**—Long-crested Jay.

Common resident of foothills and mountains, breeding mostly at from 7,000 to 9,000 feet. Performs a regular spring and autumn vertical migration, often accentuated in the autumn by severe weather. Occasional in winter some distance out on the plains.

480. **Aphelocoma woodhouseii**—Woodhouse Jay.

Have seen only the specimen in the University cabinets collected by Bragg in the foothills near Boulder in 1904. Felger has one taken by Gale on the St Vrain, October 31, 1887.

484*a*. **Perisoreus canadensis capitalis**—Rocky Mountain Jay.

Resident of the higher mountains, mostly above 8,000 feet. Have seen a few in Boulder twice during severe winter weather. Gale found young birds twice at 10,000 feet and once at 11,000, but never found nest and eggs.

487. **Corvus cryptoleucus**—White-necked Raven.

Noted at Boulder in 1894 by R. A. Campbell (Cooke). Not since recorded.

488. **Corvus brachyrhynchos**—American Crow.

Noted on plains by Gale. Seldom seen now. Blanchard reported a flock in Boulder Canyon, December 1, 1906, and Markman reported a flock, possibly the same one, on the foothills at Boulder six days later. Rockwell noted the species near Boulder, March 26, 1904.

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491. **Nucifraga columbiana**—Clarke Nutcracker.

Common resident of the mountains up to timberline. Have not seen it below 7,000 feet. Gale took two nests with eggs in 1888 and 1889, respectively, the first of which was sent to the National Museum, the other is now in the University Museum, both mentioned and described by Bendire.

492. **Cyanocephalus cyanocephalus**—Pinyon Jay.

Common locally at times, but so uncertain in its movements as to have escaped several competent observers. In August, 1907, I saw 20 on Flagstaff Mt., near Boulder. In May and June, 1907, large flocks, estimated in one instance at 200 birds, repeatedly passed over Boulder, flying just over the housetops and several times alighted in trees near the writer's house. On October 1 to 4, 1908, the pine trees on the foothills at Lyons seemed fairly alive with them. There were undoubtedly thousands of them in that vicinity then.

494. **Dolichonyx oryzivorus**—Bobolink.

For several years a dozen or more have occupied a big meadow just east of Boulder each summer and a few others have been reported not far distant, but most of the reports upon investigation develop into observations of the lark bunting.

495. **Molothrus ater**—Cowbird.

Common summer resident of plains and up to 8,000 feet or more. Gale found its eggs in the nests of *Dendroica æstiva*, *Zamelodia melanocephala*, *Empidonax trailli*, *Euphagus cyanocephalus*, *Agelaius phœniceus* (probably *fortis*) and *Geothlypis trichas occidentalis*.

497. **Xanthocephalus xanthocephalus**—Yellow-headed Blackbird.

Common summer resident of plains. Have not seen it in the mountains or foothills, but Gale places it in his list of summer mountain birds, as well as in his plains list.

498*d*. **Agelaius phœniceus fortis**—Thick-billed Redwing.

From Oberholser's treatment of the redwing sub-species it seems likely that our abundant summer redwings are all of this form. I have no definite records of *arctolegus*, but its distribution and definite records from south of this county make it seem a likely winter visitor. All of our redwings had been called *A. phœniceus*. There are some around nearly every winter and sometimes, as in the winter of 1906–7, they occur in large numbers, though whether *fortis* or *arctolegus* I cannot now say. I have found them in the mountains in summer at Nederland and at the foot of Long's Peak.

501.1. **Sturnella neglecta**—Western Meadowlark.

Abundant summer resident on plains and in lower mountain region. Occasional, at least after nesting, up to timberline. All of Gale's nests were from the plains. Some usually remain through the winter in the valley, but are not common then.

507. **Icterus galbula**—Baltimore Oriole.

A very rare bird in Colorado. Gale's notes mention a nest of five eggs taken in the mountains June 25, 1884. A specimen in Mrs. Maxwell's collection bore no locality label, I believe.

508. **Icterus bullocki**—Bullock Oriole.

Common summer resident of plains and probably less common in the mountains. I have no mountain nesting records.

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510. **Euphagus cyanocephalus**—Brewer Blackbird.

Abundant summer resident of plains and mountains up to 8,000 or 9,000 feet. Gale says, under date June 15, 1887: "About this date *Scolecophagus* [=*Euphagus*] *cyanocephalus* visits the range for some purpose or other. Do not know why." His latest nests were June 5, so it is probably a post-nesting movement such as several species engage in.

511*b*. **Quiscalus quiscula æneus**—Bronzed Grackle.

Gale found it nesting on Boulder Creek on May 20, 1886, and Blanchard reported it in Boulder Canyon in 1903.

514*a*. **Hesperiphona vespertina montana**—Western Evening Grosbeak.

Since 1901 it has been an abundant and regular winter resident of portions of Boulder, feeding upon the box-elder seeds which remain on the trees nearly throughout the winter, its presence being often detected by the broken-off seed wings under the trees. In 1908 some remained until at least May 18. Dille reported young birds at the edge of the plains, Altona, and in the mountains on South St. Vrain, in August and September, 1904.

515*a*. **Pinicola enucleator montana**—Rocky Mountain Pine Grosbeak.

Resident in mountains. Gale appears to limit it to from 9,000 feet to timberline and did not record any nests. I have only seen it occasionally in summer and autumn and not below 10,000 feet, but Felger had one taken by Gale at 9,000 feet, November 15, 1887.

518. **Carpodacus cassini**—Cassin Purple Finch.

Gale found it nesting in mountains at Ward and Duck Lake. I have seen few and only in winter at Boulder.

519. **Carpodacus mexicanus frontalis**—House Finch.

Abundant resident at base of foothills, nesting about the houses. Gale found it nesting at Gold Hill, about 9,000 feet.

521*a*. **Loxia curvirostra stricklandi**—Mexican Crossbill.

Minot's record perhaps just over county line, but Gale found it nesting in the mountains, recorded as *L. c. bendirei* (*Auk*, XXIV, 440), a subspecific name since rejected by the A. O. U. Committee on Nomenclature. Felger has one taken by Gale at 10,000 feet August 15, 1887, and one taken at 9,000 feet, November 21, 1887.

524. **Leucosticte tephrocotis**—Gray-crowned Leucosticte.

One taken by Gale in mountains on January 20, 1886, was sent to Washington. One in University collection was taken by Bragg in 1904. Blanchard and Sprague also noted it in the mountains. Felger has one taken in the county, February 2, 1888, and nine others without date. Boulder specimens from Mrs. Maxwell were used by Ridgway in preparation of his monograph.

524*a*. **Leucosticte tephrocotis littoralis**—Hepburn Leucosticte.

Gale lists it as a winter bird in the mountains of Boulder County. Ridgway used Boulder winter specimens from Mrs. Maxwell in preparation of his monograph. Felger has two taken by Gale but without data.

[525. *Leucosticte atrata*—Black Leucosticte.

One in Mrs. Maxwell's collection, but locality unknown.]

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526. **Leucosticte australis**—Brown-Capped Leucosticte.

Common resident of mountains, feeding on dead insects and seeds on the snow banks of the crest of the range in summer, often coming down to 8,000 feet or less in winter. Gale found it breeding on Bald Mountain at 11,000 to 12,000 feet.

528. **Acanthis linaria**—Redpoll.

Have seen but one, taken near Boulder, but date now unknown. Gale lists it in his mountain winter list for the county.

528*b*. **Acanthis linaria rostrata**—Greater Redpoll.

Sprague took one near Magnolia, December 9, 1885, not quite typical but assigned by Ridgway to this subspecies (Cooke).

529. **Astragalinus tristis**—American Goldfinch.

Common summer resident of plains, less common in mountains, more common in Boulder in spring migration. Twelve seen by Gale at Sunset, 7,500 feet, March 23, 1887, and a flock at Ward, March 12, 1888.

530. **Astragalinus psaltria**—Arkansas Goldfinch.

Abundant summer resident of plains and mountains.

533. **Spinus pinus**—Pine Siskin.

Resident of plains and mountains, mostly nesting in mountains to timberline but for last four years abundant in Boulder from February to July 1, nesting here and feeding upon dandelion seeds, then leaving for the mountains.

**Passer domesticus**—European House Sparrow.

I first noticed it in Boulder in 1898. Now infests the entire plains area and has entered the mountains. I found it at Jamestown in 1904.

534. **Plectrophenax nivalis**—Snowflake.

Rare winter visitor recorded from Boulder by Cooke.

538. **Calcarius ornatus**—Chestnut-collared Longspur.

Rare, recorded from Boulder by Cooke.

540*a*. **Pocecetes gramineus confinis**—Western Vesper Sparrow.

Abundant summer resident of plains, less common in mountains, where Gale took it at 11,000 feet on Bald Mountain, September 15, 1888.

542*b*. **Passerculus sandwichensis alaudinus**—Western Savannah Sparrow.

H. T. Smith informs me that he saw Boulder County specimens in Bragg's collection. Bragg writes: "I have looked through the skins that were brought from Boulder, but I do not find the Savannah Sparrow, though I am sure that I took it there."

546*a*. **Coturniculus savannarum bimaculatus**—Western Grasshopper Sparrow.

One collected by Bragg near Haystack Butte, in nesting season of 1903–4, is the only county record, specimen now in cabinets at Capitol Building, Denver.

552*a*. **Chondestes grammacus strigatus**—Western Lark Sparrow.

Abundant summer resident of plains, less common in the mountains.

554. **Zonotrichia leucophrys**—White-crowned Sparrow.

Abundant in migration, on plains and in mountains, nesting most abundantly near timberline, but common in nesting season at much lower levels. Gale's nests were taken at from 9,800 to 10,200 feet.

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554*a*. **Zonotrichia leucophrys gambelli**—Intermediate Sparrow.
Common migrant. Have taken it only in migration along the base of the foothills.

559*a*. **Spizella monticola ochracea**—Western Tree Sparrow.
Common winter resident of plains and lower mountains.

560*a*. **Spizella passerina arizonæ**—Western Chipping Sparrow.
Common summer resident from plains to 10,000 feet, at which latter altitude Gale twice took its eggs. Have no certain record of *S. passerina* for the county.

562. **Spizella breweri**—Brewer Sparrow.
Have seen but one taken at Boulder, in summer. At Silver Lake, 10,000 feet, have seen several and taken two in September.

566. **Junco aikeni**—White-winged Junco.
Common winter resident of plains and lower mountains. One specimen in University cabinets is considered hybrid, *J. aikeni* × *J. mearnsi*.

567. **Junco hyemalis**—Slate-colored Junco.
One winter specimen taken near Boulder in University cabinets.

567*b*. **Junco hyemalis shufeldti**—Shufeldt Junco.
Abundant winter resident.

567*g*. **Junco hyemalis mearnsi**—Pink-sided Junco.
Common winter resident of mountains and western edge of plains.

567.1. **Junco hyemalis montanus**—Montana Junco.
One winter specimen from near Boulder in University cabinets. Felger has two taken by Gale, but without data.

[568.1. *Junco annectens*, *Junco ridgwayi*—Ridgway Junco.
Boulder, November 25, 1892 (McGregor). Pronounced hybrid by Ridgway (Birds of North and Middle America, Part I, pp. 276–277), *J. caniceps* × *J. mearnsi*. Gale also mentions this supposed species.]

570*b*. **Junco phæonotus caniceps**—Gray-headed Junco.
Abundant winter resident of plains and foothills, breeding commonly in lower mountains and abundantly near timberline. One was taken by Bragg in summer on the mesa south of Boulder. Gale noted them in pairs at 10,000 feet near Ward on March 23, 1887. His nests were all taken at from 9,500 to 10,000 feet, from June 11 to July 5.

574.1. **Amphispiza nevadensis**—Sage Sparrow.
One taken at Left Hand by Dille, March 18, 1904.

581*b*. **Melospiza melodia montana**—Mountain Song Sparrow.
Summer resident of mountains, not uncommon. At Boulder have seen it only in migration season. Gale noted it as winter resident of plains.

583. **Melospiza lincolnii**—Lincoln Sparrow.
Common in migration on plains and mountains. Common summer resident of mountains. The 19 sets of eggs in the Gale collection were all taken at about 10,000 feet, on the ground in tufts of grass, etc.

588. **Pipilo maculatus arcticus**—Arctic Towhee.
Seen along the foothills occasionally in winter or early spring. Have seen but one in Boulder, on April 21, 1907, during a snowstorm.

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588*a*. **Pipilo maculatus montanus**—Mountain Towhee.
Abundant summer resident from base of foothills to about 9,000 feet.

591. **Pipilo fuscus mesoleucus**—Canyon Towhee.
One taken at Boulder by Howard S. Reed (H. G. Smith),, March 17, 1895.

592.1. **Oreospiza chlorura**—Green-tailed Towhee.
Common summer resident from plains to timberline. Gale took two nests at 10,000 feet on May 19, 1888, and June 30, 1890, respectively.

595. **Zamelodia ludoviciana**—Rose-breasted Grosbeak.
But one record, nesting at Longmont in 1894 (Cooke).

596. **Zamelodia melanocephala**—Black-headed Grosbeak.
Not uncommon summer resident of plains and lower mountains. Gale took seven nests in May and June and recorded it up to 8,000 feet.

597*a*. **Guiraca cærulea lazula**—Western Blue Grosbeak.
Felger took one specimen in 1903, and Dille took two and reported others at base of foothills near Altona in June, 1902. I believe these are the most northerly records in Colorado.

599. **Passerina amœna**—Lazuli Bunting.
Common summer resident of plains and foothills.

604. **Spiza americana**—Dickcissel.
Rare. One in University collection taken at Boulder in 1903 by Bragg.

605. **Calamospiza melanocorys**—Lark Bunting.
Abundant summer resident of plains. Gale says also of the mountains.

607. **Piranga ludoviciana**—Louisiana Tanager.
Not uncommon summer resident of mountains, common on plains during migration.

612. **Petrochelidon lunifrons**—Cliff Swallow.
Abundant summer resident of mountains and plains.

613. **Hirundo erythrogastra**—Barn Swallow.
Abundant summer resident of plains, less abundant in mountains. I have seen them up to 9,000 feet or more.

614. **Iridoprocne bicolor**—Tree Swallow.
Gale found it nesting on Jim Creek, June 12, 1887, and June 13, 1888, and at 10,000 feet near Ward on May 31, 1887.

615. **Tachycineta thalassina lepida**—Violet-green Swallow.
Common summer resident at Boulder and on near-by foothills, less common at other points to the northward. Gale found it nesting in the mountains but gives no data.

[616. *Riparia riparia*—Bank Swallow.
Gale mentions this species in his notes, but careful consideration of what he says leaves it doubtful as to whether this is what he saw.]

618. **Bombycilla garrula**—Bohemian Waxwing.
Irregular winter visitor of mountains and plains, erratic in its movements. A few at Boulder nearly every winter. On February 13, 1905, I saw 150 in one flock.

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619. **Bombycilla cedrorum**—Cedar Waxwing.
One taken by Bragg at Boulder, July 4, 1904, now in cabinets at the State Capitol.

621. **Lanius borealis**—Northern Shrike.
Winter resident at edge of plains, not common. One in University cabinets flew into an office in the courthouse at Boulder while chasing English sparrows and was captured.

622*a*. **Lanius ludovicianus excubitorides**—White-rumped Shrike.
Not uncommon resident of plains, but have no definite mountain records.

624. **Vireosylva olivacea**—Red-eyed Vireo.
Rare summer resident. One taken at Boulder by Bragg, now in cabinets at State Capitol.

627. **Vireosylva gilva swainsonii**—Western Warbling Vireo.
Summer resident. Taken by Sprague at Magnolia and by Minot.

629*b*. **Lanivireo solitarius plumbeus**—Plumbeous Vireo.
Summer resident of foothills and mountains. Reported by Minot and Sprague and one taken by this writer at Boulder. Minot says common up to 9,000 feet.

636. **Mniotilta varia**—Black and White Warbler.
Recorded by Minot.

644. **Helminthophila virginiæ**—Virginia Warbler.
"At Boulder, common through the latter part of May" (Minot).

646. **Helminthophila celata**—Orange-crowned Warbler.
Recorded at Boulder by Minot and taken by Bragg. I saw two at Boulder, May 21, 1904.

647. **Helminthophila peregrina**—Tennessee Warbler.
Recorded at Boulder by Minot.

652. **Dendroica æstiva**—Yellow Warbler.
Abundant summer resident of plains, less common in the mountains.

655. **Dendroica coronata**—Myrtle Warbler.
Bragg took one or two in migration in 1903 and I have seen a few since.

656. **Dendroica audubonì**—Audubon Warbler.
Common on plains in migration, common summer resident of higher mountains to timberline. Minot reported it singly and in pairs several miles out from the foothills on June 1, 1880.

661. **Dendroica striata**—Black-poll Warbler.
Rare visitor in Colorado. I saw one at Boulder on May 7, 1905, with full opportunity to study it at short range and make sure of its identity.

[674. *Seiurus aurocapillus*—Oven-bird.
Minot recorded it at Boulder and Nederland, but italicizes the fact that it was "identified by notes only," which for so rare a record hardly warrants its retention.]

675*a*. **Seiurus novoboracensis notabilis**—Grinnell Water-Thrush.
"Present at Boulder, Nederland, etc., in the latter part of May," 1880 (Minot). One taken by Bragg at Boulder, May 14, 1904, in cabinets at State Capitol.

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680. **Oporornis tolmiei**—Macgillivray Warbler.

Recorded by Minot. Found nesting in lower mountains by Gale, who says it nests up to 11,000 feet, but gives no data to sustain the statement. I have taken it at 10,500 feet in early September.

681. **Geothlypis trichas occidentalis**—Western Yellow-throat.

Common summer resident at western edge of plains.

683*a*. **Icteria virens longicauda**—Long-tailed Chat.

Common summer resident at western edge of plains.

685*a*. **Wilsonia pusilla pileolata**—Pileolated Warbler.

Common on plains in migration, common summer resident from 10,000 to 11,000 feet. *W. pusilla* may be found here, but all specimens I have had in hand were identified as *pileolata*.

687. **Setophaga ruticilla**—American Redstart.

Common in migration at Boulder, much less common as a summer resident.

697. **Anthus rubescens**—American Pipit.

Common on plains in migration, abundant summer resident above timberline. Cooke says lowest known nest is from 11,000 feet on Bald Mountain .

701. **Cinclus mexicanus unicolor**—American Dipper.

Common resident along mountain streams, nesting up to 11,000 feet. Sprague found it nesting down to 7,000 feet in Boulder Canyon. In winter a pair or two are found within the city limits of Boulder at 5,300 feet.

702. **Oroscoptes montanus**—Sage Thrasher.

Occurs sparingly on plains and in mountains. One in University cabinets. I have seen a few and it has been reported by Gale, Dille and Young.

703. **Mimus polyglottos leucopterus**—Western Mockingbird.

Not common in this county. Have seen but two or three at Boulder. Gale found it nesting at Left Hand, etc., in 1886 and 1887.

704. **Dumetella carolinensis**—Catbird.

Common summer resident of plains and lower mountains.

705. **Toxostoma rufum**—Brown Thrasher.

Not common summer resident of plains. I have seen but one. Gale found it nesting several times.

715. **Salpinctes obsoletus**—Rock Wren.

Common summer resident of foothills and mountains, locally abundant. Common also at Valmont Butte on the plains.

717*a*. **Catherpes mexicanus conspersus**—Canyon Wren.

Recorded from Boulder by Anthony, November 23, 1892, from Longmont October 20, 1907, by Burnett, and I saw one at Boulder March 23, 1907. Dille found it nesting in foothills in late March and early April, 1907.

721*a*. **Troglodytes aëdon parkmanii**—Western House Wren.

Common summer resident of plains and mountains, more commonly nesting in mountains up to 10,000 feet. Gale found it at Gold Hill on May 5, 1890. His six nests were taken at from 8,000 to 10,000 feet.

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726*b*. **Certhia familiaris montana**—Rocky Mountain Creeper.

I have seen but one with certainty, at Boulder, in winter. Sprague collected it at Magnolia. Noted at Boulder by Rockwell, January 16, 1904.

727*c*. **Sitta carolinensis nelsonii**—Rocky Mountain Nuthatch.

Resident in mountains. Reported by Sprague and Gale as *S. c. aculeata*, and by Blanchard as *S. carolinensis*. Gale found it nesting at 9,500 feet. Noted by Rockwell at Boulder, January 16, 1904.

728. **Sitta canadensis**—Red-breasted Nuthatch.

Resident. Reported by Sprague and Gale.

730. **Sitta pygmæa**—Pygmy Nuthatch.

Common resident in mountains. Seventeen sets of eggs in Gale collection were taken at from 8,200 to 10,000 feet and all but two in June.

735*a*. **Penthestes atricapillus septentrionalis**—Long-tailed Chickadee.

Common summer resident of mountains, winter resident of plains.

738. **Penthestes gambelii**—Mountain Chickadee.

Abundant resident of mountains, winter resident of plains. Eighteen nests in Gale collection were taken at from 8,200 to 10,000 feet and all but three in June. The eggs vary in color.

748. **Regulus satrapa**—Golden-crowned Kinglet.

Felger has one taken by Gale in Four-mile Gulch, August 21, 1888.

749. **Regulus calendula**—Ruby-crowned Kinglet.

Taken by Sprague at Magnolia, and by Gale several times between May 31 and September 10. Two nests are in the Gale collection, of 6 and 8 eggs respectively, the latter June 6, 1893, the other undated.

751. **Polioptila cærulea**—Blue-gray Gnatcatcher.

I saw one at Boulder on May 12, 1905, under very favorable circumstances for observation and feel sure of identity.

754. **Myadestes townsendii**—Townsend Solitaire.

Common resident in mountains, winter visitor on plains. Gale's nests are from 8,500 to 9,000 feet and mostly from abandoned mine shafts.

756*a*. **Hylocichla fuscescens salicicola**—Willow Thrush.

Gale took nest on June 13, 1884, but gives no locality except Boulder County.

758*a*. **Hylocichla ustulata swainsonii**—Olive-backed Thrush.

Rare summer resident of mountains, migrant on plains. Gale noted it on the St. Vrain as early as April 16 in 1890 and in the mountains as late as October 19 in 1889. There are two nests in his collection, one from 9,500 feet, the other without locality label.

[758*c*. *Hylocichla ustulata almæ*—Alma Thrush.

Reported by Dille in 1904, but the subspecies is not now considered valid (*Auk*, XXV, 355).]

759. **Hylocichla guttata**—Dwarf Thrush.

Sprague's Magnolia record stands alone. As the identification was at the time confirmed by Ridgway it seems best to retain the record in the absence of definite information, though perhaps a re-examination might now result in its rejection.

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759*a*. **Hylocichla guttata auduboni**—Rocky Mountain Hermit Thrush.

Common summer resident in the mountains. Gale's numerous nests were taken at from 5,800 to 10,000 feet in June and July.

761*a*. **Planesticus migratorius propinquus**—Western Robin.

Abundant summer resident from plains to timberline. Some usually remain through the winter and in the winter of 1904–5 they were abundant in Boulder, feeding upon frozen apples and woodbine berries. Gale believed that many of them have their first brood on the plains, then go into the mountains for the second. They usually become much less common in Boulder in July and August.

765*a*. **Saxicola œnanthe leucorhoa**—Greenland Wheatear.

Ridgway considers Minot's solitary record of wheatear probably of this subspecies, but admits the possibility that it is *S. œnanthe*.

766. **Sialia sialis**—Bluebird.

Gale took this species several times in the mountains and took its eggs on June 6, 1889.

767*a*. **Sialia mexicana bairdi**—Chestnut-backed Bluebird.

Summer resident of lower mountains, not usually common. On October 1, 1908, I found it abundant on the South St. Vrain, southwest of Lyons.

768. **Sialia currucoides**—Mountain Bluebird.

Common summer resident of plains and abundant in the mountains, nesting from plains to timberline.

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# THE BEMBECID WASPS OF BOULDER COUNTY, COLORADO

By S. A. Rohwer

The Bembecids form a very distinct group of wasps, being easily recognized by the sessile abdomen; three cubital cells, the second receiving both recurrent nervures; the labrum exserted beyond the clypeus; the subtransverse head, and the subtle sculpture. Most of the Bembecids have very a wide range, but they are found more abundantly in the warmer parts of the temperate zone. In color they vary very much, as in the case of *Stizus godmani* Cam. The Colorado species were recently tabulated by S. A. Johnson and S. A. Rohwer in the *Entomological News* (October, 1908, pp. 373–80); but since that paper was written a few observations have been made which necessitate some changes, and the notes on the habits of *Bembex sayi* Cress. and *Stizus godmani* Cam. are of interest.

The Boulder County species may be separated as follows:

Middle tibiae with two spurs at the apex; ocelli normal; (metathorax emarginate posteriorly; small species) . . . . . **Stizus godmani** Cam.
Middle tibiae with one spur at the apex; anterior ocellus abnormal . . . . . 1
1. Metathorax emarginate posteriorly; (abdomen banded with yellow; clypeus black) . . . . . **Bembidula ventralis** Say.
Metathorax not emarginate posteriorly . . . . . 2
2. Mesothorax above with two yellow lines; metathorax more or less yellow . . . 3
Mesothorax above black; metathorax black . . . . . 4
3. Markings yellow; pleurae and pectus without black . . **Steniolia duplicata** Prov.
Markings greenish-yellow; pleurae and pectus with black . . . **Bembex sayi Cress.**
4. First abdominal segment with two broad spots which nearly meet in the middle; scutellums black . . . . . **Bembex spinolae** Farg.
First abdominal segment with four pale spots, the two middle ones smaller and farther posterior than the lateral ones; scutellums maculated . . **Steniolia obliqua** Cress.

### **Steniolia obliqua** Cresson

This species has been found at Ward, Colo., July, 1905, at flowers of *Gilia* by Professor T. D. A. Cockerell; and at Boulder, Colo., September 8, 1908 (S. A. Rohwer).



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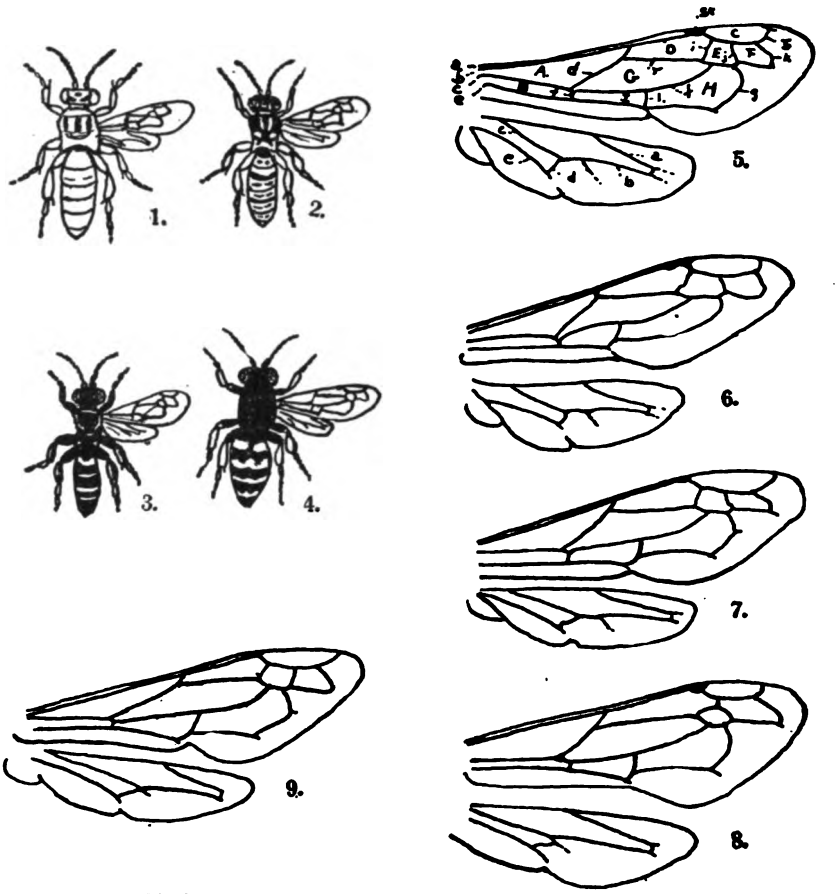


FIG. 1.—Habit drawing of *Stizus godmani flavus*. FIG. 2.—Habit drawing of *Stizus godmani lineatus*. FIG. 3.—Habit drawing of *Stizus godmani godmani*. FIG. 4.—Habit drawing of *Bembex spinolae*.

FIG. 5.—Wings of *Microbembex monodonta deltaensis:* *a*=costa; *b*=subcosta; *c*=externo-medial nervure; *d*=basal nervure; *e*=anal nervure; *f*=first recurrent nervure; *g*=second recurrent nervure; *i*, *j*, *k*= first, second and third transverse cubitus repectively; *l*=discoidal nervure; *r*=radius; *s*=cubitus; *t*=transverse median nervure; *st*=stigma; *A*=median cell; *B*=submedian cell; *C*=radical cell; *D*, *E*, *F*=first, second and third cubital cells respectively; *G*=first discoidal cell; *I*=second discoidal cell; *H*=third discoidal cell; hind wings: *a*=radial nervure; *b*=cubitus; *c*=median nervure; *d*=transverse median nervure; *e*=anal nervure.

FIG. 6.—Wings of *Bembex spinolae*. FIG. 7.—Wings of *Bembidula ventralis*. FIG. 8.—Wings of *Stizus godmani flavus*. FIG. 9.—Wings of *Steniolia obliqua*. Figs. 1–4 are enlarged about 2.75 times; the others are greatly enlarged.

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**Steniolia duplicata** Provancher

This species is quite common at Boulder during the later part of the summer, usually flying around flowers of *Chrysothamnus graveolens*.

**Bembidula ventralis** Say

A female without any black on the tibiae was taken at Boulder, Colo., July 25, 1908 by S. A. Rohwer.

**Bembex sayi** Cresson

This species is not common, and when seen is hard to catch, because of its swift flight. Three females were taken in Boulder during the first of August by S. A. Rohwer. The bands on the mesonotum are very narrow in two of the specimens, and there is more black on the abdomen. This species does not nest in colonies as do *Bembex spinolae* Farg. and *Stizus godmani* Cam., but digs its nest off by itself. I found four nests during the season in the sandy soil along a creek west of Boulder. The nest is always closed on leaving. The wasp while near her nest appears very nervous, quite contrary to the actions of *Stizus godmani* Cam. There is no hesitation as to finding the nest, but the wasp will light, dig for a few seconds, then fly off, look around to see if anything is near, then return to the nest. Sometimes when inside she would close the opening even if she stayed a few moments. On August 4, 1908, I excavated a nest which was 70 cm. long and 1 cm. in diameter. It was 10 cm. below the surface, and leaving it at an angle of about 70°. The provisioning was not completed, but it contained a Tabanid larva, one specimen of *Tabanus fratellus* Will. and three Tachinids which have bright red eyes in life. This species has a short season of flight. It lasts only about three weeks, during the later part of July and first of August.

**Bembex spinolae** Farg.

This species was rather common during August of 1907, but only one specimen was taken in 1908. All the Boulder specimens have a small yellow spot below the tegulae.

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**Stizus godmani** Cameron

On July 31, 1908, I found a colony of *Stizi* nesting in a sandy creek bed in the northwest part of Boulder, Colorado. The creek is very near the contact of the Upper Austal and Transition Life Zones, and affords a very interesting locality in which to collect Fossorial Hymenoptera. The colony of *Stizi* was near the edge of the sandy area, quite close to a field of alfalfa. It was about 10 by 15 feet in area, and closely filled with nests; often the nests were but three or four inches apart. The conduct of the colony was very similar to that of *Bembex spinolae* as described by Peckham in his interesting book on the habits of wasps. Each time a wasp left its nest it would close it tightly with the loose gravelly sand, throwing the sand in much the same manner as it would if it were digging, then tamping it down with the four anterior legs, holding the posterior pair over the abdomen. On return there was no hesitation about finding the nest; but they would alight within a few inches of it, walk to the exact spot, and, uncovering the opening, disappear into the ground. I watched this colony a short time each day, and found their working hours on warm sunny days to be from about 9:30 in the forenoon, to 4 in the afternoon. Of course there were always a few who worked over time. On cloudy and rainy days little or no activity could be noticed about the colony. Two days it rained about noon, but shortly afterward it was bright and sunny; and by 3 o'clock the whole colony was very active. About August 5 I began to notice that the number of individuals was fewer than the day I first found the colony, and from then on they became noticeably fewer; and on August 10 not a single *Stizus* was seen around the nest.

The nest is about 8 cm. in diameter and 40 cm. long, ending below the surface about 5 inches (13 cm.). It is straight, and at an angle of about 90° with the surface. It is provisioned with small flies; none of the ones I obtained could be determined because they were without wings. None of the species of *Bembex* are known to remove the wings.

The most interesting thing to me in connection with the finding of this colony was that here in the same nesting site and within an area of about 150 square feet three apparently distinct forms were found nesting. These were *S. godmani* Cam., *S. lineatus* Cam. and *S. flavus* Cam.

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(*S. flavus subalpinus* Ckll). The finding of these three different forms nesting together in the most friendly manner has led the writer to conclude that they all belong to the same species. To strengthen this conclusion no structural characters can be found to separate these widely different color forms. I have examined all my specimens carefully and have also sought for characters in the original descriptions, but without success. I would not, however, reduce these distinct color races to synonymy; on the other hand I would object to such an arrangement, because for one thing I do not consider the fact they nest together proves that they are the same, and again it is an undesirable practice to lump varieties which are easily separable. The finding them all assembled together in this one colony at Boulder does not indicate that they are always found together, and that in different localities they would not be found in different ecological areas. I would call these different forms varieties and separate them as follows:

Insect mostly black; femora entirely black; mesonotum without yellow . . . . . **godmani godmani** Cam.

Insect largely yellow or greenish-yellow; femora partly, usually entirely, yellow; mesonotum with some yellow. . . . . 1

1. Pectus black; mesonotum black with two narrow, longitudinal lines; pleurae usually marked with black; markings usually greenish-yellow . . **godmani lineatus** Cam.
Pectus yellow; mesonotum with three black lines to rest yellow; pleurae without black; markings and color bright yellow . . . . . **godmani flavus** Cam.

**Stizus godmani godmani** (Cameron).

*Stizus godmani* Cam., *Biol. Centr. Am.* (Hym.), Pl. U, fig. 8, *a*, *b*, *c*.
*Stizus agilis* Cam. (not *S. agilis* Sm.), *ibid.*, p. 102.
*Stizus godmani* Fox, *Proc. Nat. Sci. Phil.* p. 267, June, 1895.
*Stizus* (*Stizus*) *godmani* Johnson and Roh., *Ent. N.*, p. 374, October, 1908.

A number of specimens of this variety collected at Las Cruces, N. M., at flowers of *Solidago canadensis* by C. H. T. Townsend and given to me by Professor T. D. A. Cockerell vary among themselves in size (the smallest being 7 mm., the largest 10 mm.) and the abundance of yellow markings. The clypeus is entirely black, as are also the metathoracic spines in one of them. The flagellum is entirely black in another. The Boulder specimens are on the average more robust than the New Mexico ones. The abdominal bands are broader; the clypeus is in some specimens entirely yellow while in others it is yellow at the sides only; the amount

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of yellow on the legs also varies. In one female there is a small yellow spot on the pleurae.

**Stizus godmani lineatus** (Cameron).

*Stizus lineatus* Cam., *Biol. Centr. Am.* (Hym.), Vol. II, p. 108, Pl. V, fig. 7, *a*, *b*.

The amount of black on the abdomen varies. The amount of yellow on the pleurae varies; in one specimen the pleurae are entirely pale, while in another they are largely black. The pale lines on the mesonotum vary in strength, in one specimen they are very faint. There is one specimen with the lines on the mesonotum very small, and very dark. Although it has a larger number of characters in common with this variety it resembles very closely *godmani godmani*. The lines on the mesonotum are very faint, the pleura is mainly black, and the abdomen is as in *godmani godmani*.

**Stizus godmani flavus** (Cameron).

*Stizus flavus* Cam., *Biol. Centr. Am.* (Hym.), Vol. II, p. 103, Pl. V, fig. 9, *a*, *b*, *c*.
*Stizus flavus* Fox, *Proc. Acad. Nat. Sci. Phil.*, p. 268, June, 1895.
*Stizus flavus* var. *subalpinus* Ckll., *Proc. Dav. Acad. Nat. Sci.*, Vol. VII, p. 142, 1898.
*Stizus subalpinus* Johnson and Roh., *Ent. N.*, p. 374, October, 1908.

The black is usually entirely absent in the Boulder specimens. The three basal joints of the flagellum are sometimes yellow.

The following table may show the relative abundance of the three forms at Boulder. It is made from the specimens which were collected July 31, 1908, at the nesting site spoken of above, by sweeping with a net at random during the warmest part of the day.

| Name | Number of Specimens | |
|---|---|---|
| | ♀ | ♂ |
| *godmani godmani* | 8 | 1 |
| *godmani lineatus* | 1 | 3 |
| *godmani flavus* | 0 | 2 |

The finding of these three forms together and in the proportions given above suggests that they are Mendelian, and that *godmani flavus* is recessive while *godmani godmani* is dominant. It would be very interesting to obtain a large series from the same nest, and see if the different forms do exactly follow the Mendelian ratios. It is the writer's desire to carry on such experiments next season.

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# THE SILVA OF COLORADO[1]

## IV. Forest Formations and Forest Trees

By Francis Ramaley

**Forest formations.**—It is a simple matter to classify the forests of Colorado. They fall into two groups, those of the plains region and those of the mountain districts. The former are of slight economic importance at the present time but their existences suggests the possibility of tree-planting which may in time become highly profitable. River-bottom forests and pine-ridge forests occur in the plains region to the east of the continental divide, while in the western part of the state there are large areas with a growth of quaking aspen and of pinyon pine which it is difficult to classify. They might be termed either pine-ridge or foothill forests. In the mountain districts there are no trees of importance except the "evergreens."

**Forest formations of mountain districts.**—These are composed of coniferous trees, the various species of pine, spruce and fir and the single species of Douglas spruce. Generally the foothills support an open formation of rock pine[2] while in the moister canyons there are Douglas spruces.[3] In southern Colorado the pinyon pine[4] forms a conspicuous part of the foothill forest and in places in the southern and western parts of the state there are some oaks of consequence. In the montane region a closer forest exists, composed largely of lodgepole pine,[5] with some Colorado blue spruces[6] along the streams. The best timber, however, is in the sub-alpine spruce forests. These consist essentially of Engelmann spruce[7] with some admixture of limber pine,[8] sub-alpine and white fir[9] and, in places, bristle-cone pine.[10]

[1] Previous articles in this series, all published in the University of Colorado Studies, are as follows: "Trees of the Pine Family in Colorado," Vol. IV, pp. 109–122, 1907; "The Poplars, Aspens and Cottonwoods," Vol. IV, pp. 187–197, 1907; "Woody Plants of Boulder County," Vol. V, pp. 47–63, 1907.

[2] *Pinus scopulorum.*

[3] *Pseudotsuga mucronata.*

[4] *Pinus edulis.*

[5] *Pinus murrayana.*

[6] *Picea parrayana.*

[7] *Picea engelmanni.*

[8] *Pinus flexilis.*

[9] *Abies lasiocarpa* and *Abies concolor.*

[10] *Pinus aristata.*



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**Forest formations of the plains region.**—The river-bottom and pine-ridge forests occupy essentially different habitats. Along the water courses there is found a good growth of cottonwoods and willows with occasional box-elders, hackberries, mountain maples and alders. Where the stream has not cut a deep bed, and the ground slopes gently away at the sides, these river-bottom forests may be a quarter or half-mile in width. More often, however, they are much narrower. Along

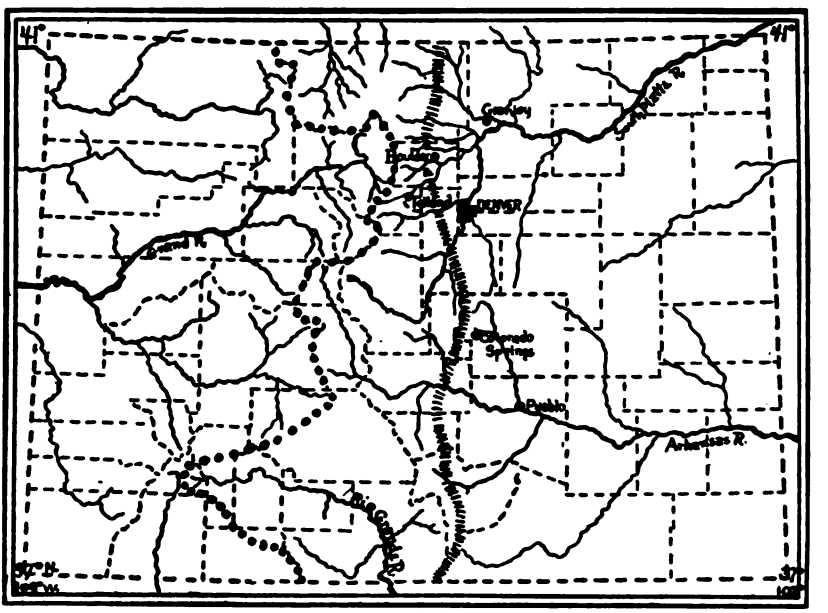


FIG. 1.—MAP OF COLORADO. The continental divide is shown by the heavy dotted line, the front range of foothills by the short horizontal lines. East of the foothills lie the great plains.

the smaller streams there is frequently a single row of cottonwoods or willows. The pine-ridge forests are on the high ground extending between adjacent streams where they grow in coarse, frequently rocky soil. Good examples of pine-ridge forests are seen along the divide between the South Platte and the Arkansas and also at the edge of the "high plains" in the northeastern part of the state. The trees of these ridges are rock pines and cedars which form scattered groups hardly to

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be dignified by the name of forest. Near Pawnee Buttes in northeastern Colorado there are limber pines instead of rock pines. To the south, and in certain parts of the western area of the state, the pinyon pine is added to the rock pine and cedar.

**Classification of forests.**—From a botanical standpoint forests may be distinguished as mesophytic and xerophytic. The former are those made up of trees requiring a moderate amount of moisture, the latter are dry-country forests capable of enduring drought; they occur in regions of slight rainfall or in situations where the run-off is rapid. Mesophytic trees in Colorado are confined to areas where there is considerable seepage water, except in the case of Engelmann spruces in the sub-alpine zone where there is much more rainfall than at lower altitudes.

It may be convenient to list the principal forest formations of Colorado in tabular form.

| Name of Formation | Relation to Moisture | Zone or Region | Principal Trees |
|---|---|---|---|
| Pine-ridge Forest | Xerophytic | Plains | Rock Pine<br>Cedar |
| River-bottom Forest | Mesophytic | Plains | Broadleaf Cottonwoods<br>Willows |
| Foothill Forest* | Xerophytic | Foothill | Rock Pine<br>Pinyon Pine |
| Canyon Forest | Mesophytic | Foothill and Montane | Narrowleaf Cottonwood<br>Willows<br>Thornapples<br>Plums<br>Cherry<br>Douglas Spruce |
| Aspen Forest | Mesophytic | Foothill and Montane | Quaking Aspen |
| Montane Dry Forest | Xerophytic | Montane | Lodgepole Pine<br>Rock Pine |
| Sub-alpine Moist Forest | Mesophytic | Sub-alpine | Engelmann Spruce<br>Firs |
| Sub-alpine Dry Forest | Xerophytic | Sub-alpine | Limber Pine<br>Lodgepole Pine |
| Sub-alpine Scrub "Wind Timber" | Xerophytic | Sub-alpine | Engelmann Spruce<br>Limber Pine<br>Fir |

* The pinyon pine is found only in the warmer and drier parts of the state. Oaks, chiefly shrubby species, enter into the foothill forest formation in certain places. They are entirely absent from the foothills north of Denver.

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**Distribution of species.**—The tree flora of the state embraces fifty-five species belonging to twenty genera. Most of the individuals, as well as the species in general, are found in the foothill, montane and sub-alpine zones of plant life. Timberline, at about 11,000 or 12,000 feet above the sea, is the upper limit of tree growth, although some shrubby willows occur in the alpine zone above. As noted in the preceding pages, the trees of the plains are to be found only along water courses or on the pine ridges of the high divides between streams. In the following table the general distribution of each tree is stated in relation to the continental divide, which extends north and south through the state, dividing it into nearly equal parts. It will be noticed that nearly all of the trees occur both east and west of the divide, somewhere in their distribution. As a matter of fact the same species does not necessarily occur at opposite points east and west of the main range. Those oaks, for example, which are present in the northwestern part of the state do not cross to the foothills of the eastern slope in northern Colorado but are found at Colorado Springs and southward. The distribution of the pinyon pine is similar. Many of the high-altitude trees extend far north to British Columbia and even Alaska. A considerable number range to the Pacific coast, but only a few show a distribution far eastward.

**Limits of tree distribution.**—The upper limit of tree growth, or timberline, is variable as to altitude. On north exposures the trees do not extend so high up the mountain side as they do on the warmer and less windy south slope. Cold, wind and dryness all combine to limit the upward extension of forests on mountains. At timberline are found scattered clumps of wind-blown trees often contorted into fantastic shapes.[1] At the lower limit of forest growth, on the foothills and mesas adjoining the plains, the trees are unable to extend out to the plains largely because of the fine soil which supports a thick covering of grasses and does not permit trees to become started. Differences in climate are also important. The plains have colder winters and warmer summers, than the adjacent foothills.[2] In the mountain parks, which are

[1] This subject is discussed with some completeness by Mr. W. S. Cooper in an article referred to in the bibliography. From 11,000 to 12,000 feet may be considered the usual limit of trees.

[2] A comparison of the climates of plains and foothills is made by the present writer in the article referred to in the bibliography: "Studies in Mesa and Foothill Vegetation."

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| Name of Tree | Relation to Continental Divide | Zone or Region of Occurrence |
|---|---|---|
| Pinus aristata | East and West | Montane, Sub-alpine |
| edulis | East and West | Foothill |
| flexilis | East and West | Sub-alpine, Montane (Foothill) |
| murrayana | East and West | Montane, Sub-alpine (Foothill) |
| scopulorum | East and West | Foothill, Montane |
| Picea engelmanni | East and West | Sub-alpine, Montane |
| parryana | East and West | Montane, Foothill |
| Pseudotsuga mucronata | East and West | Foothill, Montane |
| Abies concolor | East and West | Montane, Foothill |
| lasiocarpa | East and West | Sub-alpine, Montane (Foothill) |
| Sabina monosperma | East and West | Foothill (Plains) |
| scopulorum | East and West | Foothill, Montane, Plains |
| utahensis | West | Foothill, Plains |
| Populus acuminata | East and West (?) | Foothill, Plains |
| angustifolia | East and West | Foothill, Montane, Plains |
| balsamifera | East and West | Montane, Foothill |
| sargentii | East | Plains, Foothill |
| tremuloides | East and West | Foothill, Montane, Sub-alpine |
| wislizeni | East and West (?) | Plains, Foothill |
| Salix amygdaloides | East and West | Plains, Foothill (Montane) |
| bebbiana | East and West | Foothill, Montane, Plains |
| exigua | East and West | Plains, Foothill (Montane) |
| lasiandra | East and West | Foothill, Plains (Montane) |
| nuttallii | East and West | Foothill, Montane |
| sessilifolia | East and West | Foothill, Plains |
| Betula andrewsii | East | Foothill (Montane) |
| fontinalis | East and West | Foothill, Montane |
| Alnus tenuifolia | East and West | Foothill, Montane (Plains) |
| Quercus gambelii | East and West | Foothill |
| leptophylla | East and West | Foothill |
| nitescens | East and West | Foothill |
| utahensis | East and West | Foothill |
| Celtis douglasii | East (?) West | Foothill |
| reticulata | East and West | Foothill, Plains |
| Cercocarpus ledifolius | West | Foothill, Plains, Montane |
| Amelanchier alnifolia | East and West | Plains, Foothill, Montane |
| Crataegus chrysocarpa | East | Foothill |
| coloradensis | East | Foothill |
| coloradoides | East | Foothill |
| doddsii | East | Foothill |
| erythropoda | East and West | Foothill |
| laurentiana | East | Foothill |
| occidentalis | East | Foothill |
| rivularis | West | Foothill |
| saligna | West | Foothill |
| Prunus americana | East | Foothill, Plains |
| melanocarpa | East and West | Foothill, Plains, Montane |
| pennsylvanica | East | Foothill, Montane, Plains |
| Robinia neomexicana | East and West (?) | Foothill, Plains |
| Acer glabrum | East and West | Foothill, Plains, Montane |
| grandidentum | East and West | Foothill, Montane |
| interior | East and West (?) | Plains, Foothill |
| Rhus glabra | East and West | Foothill, Plains |
| Rhamnus purshiana | West | Foothill |
| Fraxinus anomala | West | Foothill, Plains |

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certain broad valleys of the foothill and montane regions, while forests are present on the hillsides there are only a few scattered trees on the level ground below. This absence of trees is probably to be accounted for by the fineness of soil and greater severity of climate.

**Colorado forests in former geologic times.**—Professor T. D. A. Cockerell, the authority on fossil plants of the Rocky Mountains, has recorded a large number of species of trees which formerly grew at Florissant and at other places in Colorado. The most easily accessible of his papers are referred to in a footnote.[1] It appears that the forests of Miocene times were made up of pines, cedars, willows, cottonwoods, birches, alders, oaks, hackberries, June berries, thornapples, locusts, sumacs, maples, buckthorns and ashes, besides a number of eastern and southern trees which do not now exist in the state at all. Among these others were: mulberry, soapberry, acacia, redbud and walnut. No doubt the climate was much warmer at that time and, in the mountains at least, more moist. The fossil remains of many of the leaves are very perfect and the trees can be told with considerable certainty. We may be sure that for thousands and perhaps millions of years the pines, cottonwoods, cedars and thornapples have been an important part of the vegetation of this part of the world.

**Literature dealing with Colorado trees.**—The well-known manuals of botany of the eastern United States such as Gray's and Britton's, describe certain of the tree species of Colorado. So, also, the *Rocky Mountain Botany*[2] by Professor John M. Coulter, issued many years ago, gives descriptions of a part of the arborescent flora of the state. Unfortunately there is no new work which gives all of the trees nor one which discusses the forest formations. Probably the most useful single book is the new work of Dr. Britton.[3] Anyone interested in the larger aspects of forestry will find useful articles from time to time in the *National Geographic Magazine* and in the magazine, *Conservation.*

[1] COCKERELL, T. D. A. "Florissant; A Miocene Pompeii," *Popular Science Monthly*, Vol. LXXIV, pp. 112–126, 1908. "Some Results of the Florissant Expedition of 1908," *American Naturalist*, Vol. XLII, pp. 569–581, 1908.

[2] A new edition of this work, rewritten by Professor Owen Nelson of the University of Wyoming, is to be issued in 1910.

[3] BRITTON, N. L., *North American Trees*, pp. 1–894, New York, 1908.

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This latter publication is the organ of the American Forestry Association. The *Flora of Colorado*[1] is valuable for the professional botanist—indeed it is a perfect mine of information—but is rather too technical in its treatment for the amateur. The present writer has made free use of this work in the preparation of his account of the tree species of Colorado.

At the close of the present paper are noted some of the books and special articles which deal with Colorado trees. It is not intended as a complete bibliography, but merely as a useful working list for reference.

**Economic considerations.**—The great importance of forests is now recognized on every side and it is desirable that the people of Colorado should know something of the trees of the state and of their value. Perhaps the most important function of forests in mountain districts anywhere is to conserve the water and prevent the land from washing. But they may serve also to supply much needed timber for mining and manufacturing purposes. In many parts of the state large areas of the original forest have been cut and burned over so that there is now much waste land in the foothills and in the mountains. Since this is neither fit for mining nor agriculture it should, in time, come to be valuable for purposes of forest growth. For the most part, reproduction in the forests of Colorado is rapid and all that is needful to insure the reforestation of old lands is careful supervision and protection. It matters little from the standpoint of the botanist or one interested in forests how this protection is attained. It may be done either by federal or state authority. Private supervision of forest lands elsewhere, at least, has not been successful. Not only must illegal cutting be prohibited but fires must be kept out. If this is attended to the forests will take care of themselves.

The waste and desolation which come in the wake of forest destruction is well known. France has spent millions of dollars in reforestation of mountain slopes. Spain, Greece, Turkey, northern Africa and China have suffered because there was no supervision of forests. Conditions in China have been recently described:

> The ruthless destruction of the forests in northern China has brought about, or has aided in bringing about, desolation, just as the destruction of the forests in central Asia aided in bringing ruin to the once rich central Asian cities; just as the destruction of the forests in northern Africa helped toward the ruin of a region that was a fertile granary in

[1] RYDBERG, P. A., *Flora of Colorado*, Bull. 100, Colo. Agric. Exper. Sta., pp. 1–447, Ft. Collins, 1906.

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Roman days. Short-sighted man, whether barbaric, semi-civilized, or what he may mistakenly regard as fully civilized, when he has destroyed the forests, has rendered certain the ultimate destruction of the land itself. . . . . This is just one of those matters which it is fatal to leave to unsupervised individual control. The forests can only be protected by the state, by the nation, and the liberty of action of individuals must be conditioned upon what the state or nation determines to be necessary for the common safety.[1]

With the continued rise in the price of all kinds of wood the forests of Colorado may be made one of the great economic assets of the state in the future. They will serve for protection to the headwaters of our streams and if rightly managed will furnish a constant supply of timber for industrial and building purposes.

The cottonwoods of the gulches and river bottoms are, to a considerable extent, made use of for fences and for other rough construction work. If farmers and others would take pains to plant these and other more valuable trees they would secure profitable returns. Many of the smaller trees of the state are proving useful as shade trees and still others are being introduced into cultivation for ornamental purposes in parks and private grounds. The thornapples are especially promising as ornamental trees because of both flowers and fruit, while the cottonwoods, hackberries and box-elders are useful for shade.

**Scope of the present study.**—The following pages are given up to keys for the determination of the species of trees in the state, together with a somewhat full account of each of the trees of the pine family. It was thought best to describe these trees in some detail on account of their economic value and the general interest which attaches to them. It is impossible at the present time to state fully the distribution of most of the species within the state. Only a small part of the area has been examined by botanists so that the limits of distribution are imperfectly known.

**How to use the keys.**—It is necessary to look at Key I for the "evergreens" (trees of the pine family) and at Key II for any other trees. In each of the keys two choices are open to the student at first, named respectively **1a** and **1b**. These two are to be read carefully and whichever describes the tree under consideration will be used as the beginning of the classification. At the right of line is a figure in parenthesis

[1] ROOSEVELT, THEODORE, "Message to the Congress of the United States," December 8, 1908.

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which refers the user of the key to the next line which is to be consulted. This may give at once the desired name or it may refer to a still lower line. At any rate the process is to be continued until the name of the genus is found. Noting the number of the genus, as well as the name, the student should now turn to the proper place in the following pages and, with the aid of the special key, determine the exact species. Both the scientific and English names are given since both are likely to be useful to one interested in botany or forestry.

KEY I. FOR IDENTIFICATION OF COLORADO EVERGREENS

**1a.** Trees with needle-like foliage leaves; fruit a cone. (2)

**1b.** Trees with scale-like, overlapping leaves, fruit a small berry (cedars). Genus 5. **Sabina**

**2a.** Foliage leaves (needles) in bundles of two or more surrounded at base by a short sheath. Leaves mostly more than 25 mm. (1 in.) long. Cones hard and woody when mature. Genus 2. **Pinus**

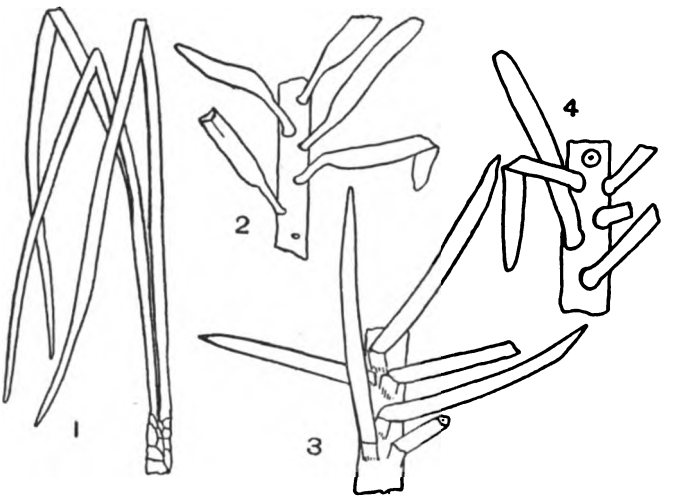


FIG. 2.—LEAVES OF CONIFEROUS TREES. 1. Pine (*Pinus*); 2. Douglas Spruce (*Pseudotsuga*); 3. Spruce (*Picea*); 4. Fir (*Abies*).

**2b.** Foliage leaves (needles) solitary, not in bundles; mostly less than 25 mm. (1 in.) in length. Mature cones leathery or papery; not hard and woody. (3)

**3a.** Leaves jointed near the base, the lower part of the leaf brown and woody and remaining on the branchlet after the rest of the leaf has fallen. Leaves in our species stiff and four-angled, not flat. Cones pendulous. Genus 2. **Picea**

**3b.** Leaves not brown nor woody at base, flat. When they fall off they leave a scar but no part of the leaf remains. (4)

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**4a.** Leaves rather soft; narrowed toward the base into a short stalk which broadens slightly at the point of attachment. Leaf-scars transversely elliptical. Cones pendulous, the projecting bracts three-pointed. Genus 3. **Pseudotsuga**

**4b.** Leaves somewhat stiff, very slightly narrowed at base; leaf scars rather large, circular in outline. Cones erect, dark purple or blackish or sometimes yellow. Genus 4. **Abies**

KEY II. FOR IDENTIFICATION OF DECIDUOUS TREES

**1a.** Leaves simple; not composed of leaflets. (2)

**1b.** Leaves compound; of three or more leaflets. (11)

**2a.** Trees without thorns or spines. (3)

**2b.** Trees with thorns or spines. (10)

**3a.** Trees with rough bark of bitter taste; leaves much longer than broad; flowers and fruits in erect catkins; seeds cottony (willows). Genus 7. **Salix**

**3b.** Trees with white or light gray branches; flowers and fruits in drooping catkins; seeds cottony (cottonwoods, poplars and aspen). Genus 6. **Populus**

**3c.** Trees with conspicuous flowers and fleshy fruits (cherry, plum and June berry). (4)

**3d.** Trees not falling under **3a**, **3b** or **3c**. (5)

**4a.** Leaves with margin finely toothed all around (plum and cherry). Genus 15. **Prunus**

**4b.** Leaves with margin toothed only in the upper half (June berry). Genus 13. **Amelanchier**

**5a.** Leaves with veining pinnate; a distinct mid-rib with lateral veins extending from it. (6)

**5b.** Leaves with palmate veining; the main veins extending from the base of the leaf-blade like fingers from the palm of the hand (maples). Genus 17. **Acer**

**6a.** Leaves elm-like; not symmetrical at base (hackberry). Genus 11. **Celtis**

**6b.** Leaves not elm-like; usually symmetrical at base. (7)

**7a.** Leaves very small; only 15 to 25 mm. (⅝ to 1 in.) long (mountain mahogany). Genus 12. **Cercocarpus**

**7b.** Leaves mostly 35 mm. (1⅜ in.) long, or longer. (8)

**8a.** Leaves pinnately lobed or cleft; the lobes and sinuses rounded; fruit an acorn (oaks). Genus 10. **Quercus**

**8b.** Leaves merely toothed or slightly sharp-lobed; flowers and fruits in catkins (alders and birches). (9)

**8c.** Leaves finely toothed or nearly entire; fruit berry-like, in small clusters (cascara sagrada). Genus 19. **Rhamnus**

**8d.** Leaves finely toothed or wavy margined; fruit a winged samara (ash). Genus 20. **Fraxinus**

**9a.** Leaves rough and coarse; with both fine and coarse teeth (alder). Genus 9. **Alnus**

**9b.** Leaves rather smooth; bright green. Genus 8. **Betula**

**10a.** Spines numerous, sharp pointed (thornapple). Genus 14. **Crataegus**

**10b.** Spines few, scattered (plum). Genus 15 **Prunus**

**11a.** Trees with short thorns in pairs (locust). Genus 16. **Robinia**

**11b.** Trees without thorns; leaflets more than four pairs (sumac). Genus 18. **Rhus**

**11c.** Trees without thorns; leaflets 3, 5 or 7 (box-elder). Genus 17. **Acer**

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## Genus 1. **PINUS**, PINE

Evergreen trees and shrubs growing often in dry and rocky situations. Foliage leaves needle-shaped growing usually in bundles of 2 to 5 leaves. The foliage leaves are borne on very short twigs (dwarf shoots), which arise in the axils of appressed scale leaves. Staminate cones small, yellow or reddish, growing in clusters and shedding their pollen in late spring or early summer. Carpellate cones either solitary or clustered. Cone scales thick, becoming woody. The cones ripen the second year or later.

**1a.** Leaves in bundles of 4 to 6; medium-sized or small trees, chiefly in high altitudes. (2)

**1b.** Leaves in bundles of 2 or 3. (3)

**2a.** Leaves 25 to 40 mm. (1 to 1⅝ in.) long. Cones 7 to 9 cm. (2¾ to 3½ in.) long, the scales with curved, needle-pointed spines. **Pinus aristata**

**2b.** Leaves 3.5 to 7.5 cm. (1⅜ to 3 in.) long. Tree of wind-swept mountain sides or exposed points. Cones large, 7 to 25 cm. (2¾ to 9¾ in.) long, the scales smooth, without spines **Pinus flexilis**

**3a.** Leaves short, 2 to 4 cm. (¾ to 1½ in.) long, generally in pairs; cones small, about the same length as the leaves, seeds large (about the size of a common white bean), edible. A tree or shrub found in the foothills south and west. **Pinus edulis**

**3b.** Leaves longer, 4 to 12 cm. (1½ to 4¾ in.) long; in bundles of 2 or 3. (4)

**4a.** Leaves usually about 10 cm. (3⅞ in.) long, but shorter in exposed situations; sometimes longer. Cones 6 to 9 cm. (2⅜ to 3½ in.). A tree of foothills and river bluffs and extending occasionally to an altitude of 10,000 ft. **Pinus scopulorum**

**4b.** Leaves 3 to 6 cm. (1¼ to 2⅜ in.) long; cones about same length as leaves. A tree of foothills and mountains, often forming pure forests at altitudes of 7,500 to 9,500 ft. **Pinus murrayana**

**Pinus aristata** Engelm. BRISTLE-CONE PINE. Leaves in bundles of 4 or 5, dark green, 2.5 to 4 cm. long. Cone 7 to 9 cm. long. Cone scales somewhat thin, each with a slender curved bristle about 6 mm. long. Seeds winged.

A bushy tree of small or medium size with the main trunk short, numerous strong branches starting rather low down. Bark thin, pale or milky white on small branchlets, dark gray or brown on the main trunk. Wood soft and not durable; specific gravity 0.5572.

Rocky and gravelly slopes at high altitudes in the mountains from central and southern Colorado to Utah, Nevada, southern California and Arizona.

**Pinus flexilis** James. LIMBER PINE, WHITE PINE. Leaves in bundles of 5; stout, rigid, dark green, 3.5 to 7.5 cm. long. Cone very large, 7 to 25 cm. long. Cone scales smooth, without bristle points. Seeds large, with a narrow wing which usually adheres to the cone scale when the seeds drop.

A medium-sized tree with a short main trunk and abundant lateral branches, growing in wind-swept situations and hence often much distorted. Bark of twigs and branches pale gray or whitish, becoming dark brown on older trunks. Wood light; specific gravity 0.4358; sometimes used for lumber which is, however, full of knots.

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Eastern slope of Rocky Mountains from Alberta to western Texas, westward through Montana to Nevada and California. It is the principal tree of the upper foothills of the eastern slope in Montana. In Nevada it forms extensive forests. In Colorado and Wyoming it is usually scattered in exposed situations at rather high altitudes but a few trees are found on the bluffs west of Pawnee Buttes, Colo., at an altitude of 5,000 feet.

**Pinus edulis** Engelm. PINYON, NUT PINE. Leaves in bundles of 2, rarely 3; dark green, curved, stiff, 2 to 4 cm. long. Cone when mature about the same length as the leaves and nearly spherical; cone scales few, thick, spiny tipped. Seeds large, about the size of a small white bean, the narrow wing of the seed remaining adherent to the cone scale when the seed falls.

A small or medium-sized tree, much branched and shrublike. Bark rather thin; that of young branchlets orange colored, becoming at length gray or brown. Wood rather durable; specific gravity 0.6388; brittle, close grained. Used for fuel and fencing and sometimes for preparation of charcoal. In western Texas it has been sawed for lumber. The large, edible seeds, known as "pinyon nuts," collected by Indians, are on sale by fruit dealers in the towns and cities of Colorado.

Eastern foothills of the outer range of the Rocky Mountains from near the Palmer Lake divide south to western Texas and west to Arizona and southwestern Wyoming. In places it forms open forests with the rock pine; mixed with junipers it is common on the hills and table lands of western Colorado. It does not extend to very high altitudes.

**Pinus scopulorum** (Engelm.) Lemmon. ROCK PINE. Leaves in bundles of two or three, variable as to number even on the same tree; stout, dark yellowish green, often in bottle-brush arrangement at the ends of naked branches; 8 to 15 cm. long. Cone 6 to 9 cm. long, the cone scales each with a stout sharp prickle. The young cones are erect the first summer; when fully grown they are horizontal or slightly declining.

A handsome spreading tree, the largest of our pines, with thick, deeply-furrowed, reddish bark becoming very thick on old trees. Wood hard and strong but differing greatly in quality; where abundant it is sawed into lumber or used for railway ties and mine timbers. The specific gravity is 0.4619.

Hills and ridges of western Nebraska to Rocky Mountain region and from Montana to Arizona and New Mexico.

On account of its resistance to drought this tree should be a valuable one for planting in semi-arid districts. The large seeds germinate freely and the trees are easily grown when given reasonable care. Sometimes called "yellow pine" or "blackjack."

**Pinus murrayana** "Oreg. Com." LODGEPOLE PINE. Leaves in bundles of 2, yellow-green, 3 to 6 cm. long. Cone about the same length as the leaves, very persistent, often remaining attached three or four years after ripening; cone scales with short, sharp prickles.

A tall, straight tree, generally growing in dense groves on north slopes in the higher foothills. The trees have been considered of little value for lumber but they are certainly most useful in holding the soil and in protecting snow from too rapid melting. Seeds of this pine, unlike those of most species, retain their vitality for a number of years. Burned districts become reseeded by the opening of the cones which takes place on account of the heat produced by the fire. Wood rather light and soft, not durable; specific gravity 0.4096. Used to some extent for ties, mine timber and fuel when better wood is not available.

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Recently developed methods of seasoning and preservative treatment promise to make the lodgepole pine valuable for railway ties and mine timbers.

Montana to southern Colorado, west to California and Alaska. In the higher foothills of Colorado.

## Genus 2. **PICEA**, The True Spruces

Tall, conical, evergreen trees with tapering trunk and thin, scaly bark. Leaves needle-shaped, four-angled or flattened (ours four-angled) with sharp points. The leaves extend out from all sides of the twig in bottle-brush fashion; they are not in bundles as in pine but occur singly. Leaves jointed near the base, the lower part (sterigma) becoming woody and persistent after the fall of the leaf. Bare twigs thus appear roughened with short, truncate elevations. Cones pendant, chiefly on the upper branches.

1a. Leaves rigid, needle pointed, blue-green or silvery, branchlets smooth or at least not hairy. Cones about 7 cm. (2¾ in.) long. Frequent in cultivation. **Picea parryana**

1b. Leaves less rigid, abruptly pointed, having a somewhat skunk-like odor when bruised. The branchlets are generally described as pubescent but are smooth in specimens grown at high altitudes. Cones about 4 cm. (1⅝ in.) long. **Picea engelmanni**

**Picea parryana** (Andree) Sarg. Colorado Blue Spruce. Leaves stout, rigid, four-angled, mostly 25 to 30 mm. long but on cone-bearing branches shorter and curved. Generally the leaves stand out from all sides of the branchlets but sometimes the under surface of horizontal branches has few leaves. Color of leaves generally silvery or bluish-green when young, becoming duller with age. Individual specimens differ greatly in this regard. Cones about 7 cm. long.

A tree of medium size. Bark broken into small oblong, platelike scales; on old trunks thick and deeply grooved. Wood light, soft, weak; specific gravity 0.3740.

Along the mountain streams of eastern Colorado, west to Utah and north to the Wind River Mountains of Wyoming, occurring singly or in small groves.

Much cultivated for ornament in this country and in Europe. There are numerous horticultural varieties propagated by grafting.

**Picea engelmanni** (Parry) Engelm. Engelmann Spruce. Leaves ridged above and below so that they are rather four-sided; awl pointed; not so stiff as those of the blue spruce. Leaves at first covered with a bluish or silvery bloom which disappears later; slender, 25 to 30 mm. long on the ordinary branches but shorter on cone-bearing twigs. Cones 3 to 5 cm. long.

A large conical tree of the higher foothills and mountains; near timber limit a straggling, prostrate shrub. Bark thin, broken into large, thin, loose scales. Wood light, soft, close grained, not strong; specific gravity 0.3449. Frequently used for lumber and for making charcoal. The bark has been employed for tanning leather. In some localities the Englemann spruce has been largely cut for railway ties and to some extent for telegraph and telephone poles. It should be valuable for wood pulp.

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In the Cascade, Selkirk and Rocky Mountain ranges of British Columbia and Alberta, south through the mountain states to New Mexico and Arizona, west to Oregon. It is by far the more abundant of our two species of *Picea* and is the common tree near timberline where it forms scrubby mats. In such situations it seldom bears cones. At 10,000 to 11,000 feet altitude it reaches its largest size.

The Engelmann spruce has been planted for ornament in the eastern United States and in Europe. Sometimes it is mistaken for the blue spruce. These two species of *Picea* are not easily distinguished; however, the size of the cones is a marked feature.

## Genus 3. **PSEUDOTSUGA,** DOUGLAS SPRUCE

Tall conical trees with thick, furrowed bark and strong wood resembling in quality the best hard pine. Branches generally ascending, the branchlets spreading; general appearance more feathery than true spruce. Leaves linear, flat, narrowed at base to a short leaf-stalk. Cones pendant; usually scattered over the tree; not confined to the upper branches; cone scales persistent; bracts with prominent teeth giving the cone a fringed appearance. Three species of this genus are known; one in Japan, the other two in western North America.

**Pseudotsuga mucronata** (Raf.) Sudw. DOUGLAS SPRUCE. Leaves rather soft, not rigid, flat, channeled above and ridged below, 20 to 35 mm. long, dark yellow-green in color, narrowed to a short stalk; leaf scars not prominent. Cones pendulous, 5 to 10 cm. long, the bracts projecting beyond the scales. Each bract with two lateral teeth and the midrib projected as a rigid awn.

A tree of handsome conical form, especially when young; reaching the greatest size in the moist forests of Oregon and Washington. Bark on young trees smooth and thin; on older trees very thick and deeply furrowed. Wood hard; light red or yellow; specific gravity 0.5157; largely manufactured into lumber in the Pacific Northwest where it is generally known as "Oregon pine," "Douglas fir" and "red fir." Employed for fuel, railway ties and piles; in Colorado used as Christmas trees.

British Columbia and Alberta southward through hills and mountains to northern Mexico and western Texas.

Frequently planted as an ornamental and shade tree in Europe and the eastern United States. Numerous varieties are distinguished in cultivation.

## Genus 4. **ABIES,** THE FIRS, BALSAMS

Tall conical trees of colder regions and mountain districts. Leaves linear, flat, sessile; grooved above and having a notched apex. On the upper cone-bearing branches the leaves are often curved and thick, with the upper surface convex instead of grooved. Cones erect; purplish-black or yellow, formed of closely overlapping scales; exuding a bal-

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samic resin. The cone-scales and bracts separate from the axis while this is still on the tree; hence complete cones are never found under the trees.

1a. Leaves of vigorous lower branches 2.5 to 4.5 cm. (1 to 1¾ in.) long; resin ducts of the leaves deeply imbedded, not close to the epidermis. Cones purple or nearly black. **Abies lasiocarpa**

1b. Leaves of vigorous lower branches 4.5 to 7.5 cm. (1¾ to 3 in.) long; resin ducts of the leaves close to the epidermis of the under surface; cones yellow, green or purple. Not found in northern Colorado. **Abies concolor**

**Abies lasiocarpa** (Hook.) Nutt. SUB-ALPINE FIR. Leaves flat, with prominent mid-vein, bluish-green; on vigorous lower branches 2.5 to 4.5 cm. long; on old parts and on cone-bearing twigs much shorter. Cone oblong-cylindrical, rounded, erect, purple or nearly black, 6 to 10 cm. long.

A medium-sized tree with branches extending nearly to the base of the trunk; bark of young trees pale gray and smooth; on old trees broken with shallow fissures and roughened with thin orange-colored scales. Wood light, not strong, nor durable; of little value but sometimes used as firewood; specific gravity 0.3476.

High altitudes in the mountains throughout western North America.

**Abies concolor** Lindl. WHITE FIR. Leaves mostly in two rows on the branchlets, more or less erect; on lower branches flat, straight, with rounded or pointed apex; length 4.5 to 7.5 cm.; on cone-bearing twigs shorter and generally curved. Cone ellipsoid-cylindrical, 7 to 13 cm. long, grayish-green, purple or yellow, with broad, closely imbricated scales. A large tree with narrow spire-like crown; the short, main branches bearing long, lateral branchlets; the whole forming frond-like masses of foliage. Bark of old trunks becoming very thick, deeply divided into broad, rounded ridges. Wood light, close grained, not strong nor durable; specific gravity 0.3638.

From the Pike's Peak region of the Rocky Mountains of Colorado west to Oregon and south to northern Mexico and Arizona, reaching its greatest development in the Sierras of California. It is the only true fir in the arid regions of the Great Basin.

## Genus 5. **SABINA**, CEDAR

The trees and shrubs of this genus are often classified with the junipers and placed in the genus *Juniperus*. It seems best to separate them because the cedars have such a very different general appearance. Leaves of true junipers are sharp-pointed and awl-shaped; instead of being scale-like and rather soft to the touch, as are the leaves of cedars. It is to be noted, however, that the leaves of young cedars are sharp-pointed and look like the leaves of junipers.

1a. Fruit when ripe blue, juicy, resinous. (2)

1b. Fruit when ripe reddish-brown, dry, fibrous. Small tree of western Colorado and westward. **Sabina utahensis** (Engelm.) Rydb.

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2a. Leaves with minute teeth near the apex; fruit generally one-seeded. **Sabina monosperma** (Engelm.) Rydb.

2b. Leaves entire at apex; fruit generally several-seeded. The common cedar of the eastern slope. **Sabina scopulorum** (Sarg.) Rydb.

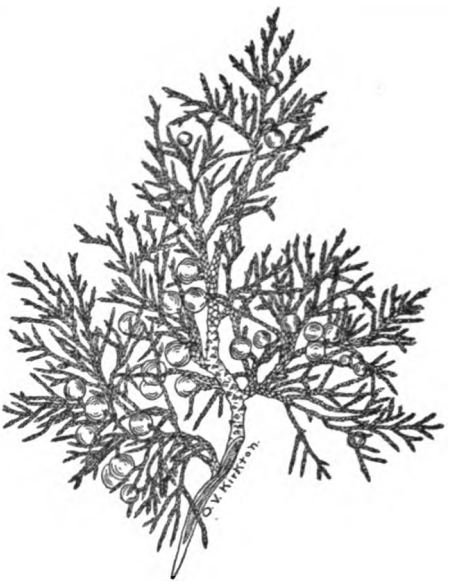

FIG. 3.—ROCKY MOUNTAIN RED CEDAR (*Sabina scopulorum*). ×½.

## Genus 6. **POPULUS**, POPLARS, COTTONWOODS, ASPEN

These are the most important trees of the river-bottom and canyon forests. The broadleaf cottonwoods seldom extend far up the canyons and the narrowleaf trees seldom get down to the lower altitudes of the plains region.

1a. Leaf-stalk much flattened laterally where attached to blade of leaf. Leaves easily rustled by the wind. (2)

1b. Leaf-stalk nearly cylindrical where attached to blade. (3)

2a. Leaf-blade somewhat circular in outline with short-pointed apex. Bark very white. **Populus tremuloides** Michx. "Quaking Aspen"

2b. Leaf-blade broadly triangular or heart-shaped; marginal teeth less than ten on each side of blade (tree of southern Colorado). **Populus wislizeni** (Wats.) Sarg. "Broadleaf Cottonwood"

2c. Leaf-blade broadly triangular or heart-shaped; marginal teeth more than ten on each side of blade. (This is the common broadleaf cottonwood at Denver and in northern Colorado.) **Populus sargentii** Dode. "Broadleaf Cottonwood"

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FIG. 4.—BROADLEAF COTTONWOOD (*Populus sargentii*). ×½.

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**3a.** Leaf-stalk stout; one-third the length of blade or less; blades narrow. **Populus angustifolia** James. "Narrowleaf Cottonwood"

**3b.** Leaf-stalk slender, one-half the length of blade or longer. (4)

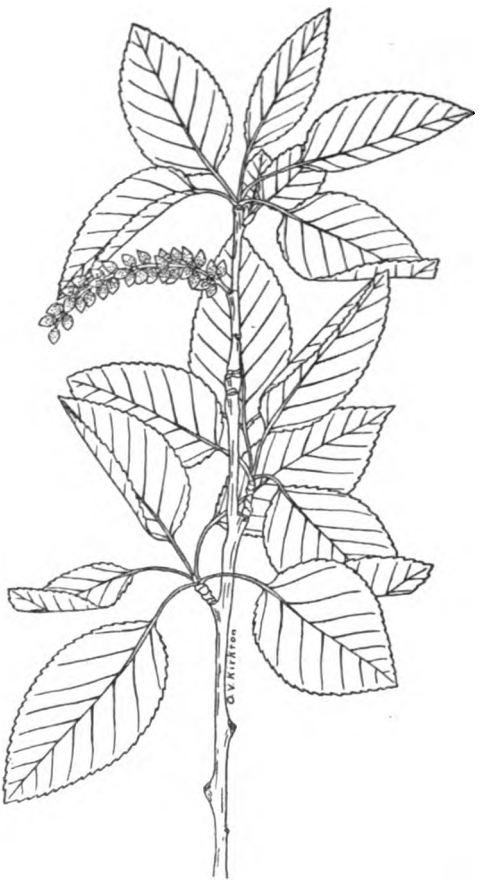

FIG. 5.—NARROWLEAF COTTONWOOD (*Populus angustifolia*). ×½.

**4a.** Leaf-blades ovate; rounded at base, under surface whitish; veins prominent. Trees of mountain districts. **Populus balsamifera** Linn. "Balsam Poplar"

**4b.** Leaf-blades lance-ovate, generally narrowed at base. Tree of canyons and the plains region. **Populus acuminata** Rydb. "Lanceleaf Cottonwood"

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## Genus 7. **SALIX**, Willow

In addition to the trees here listed there are about twenty species of shrubs in Colorado belonging to the genus *Salix*. Some of these extend above timberline, forming, in places, dense thickets three or four feet high.

**1a.** Leaves-lanceolate, finely serrate, pointed. (2)

**1b.** Leaves ovate, finely toothed or nearly entire, sometimes lance-elliptic or ob-ovate. (3)

**1c.** Leaves linear or narrowly lanceolate, silvery, at least when young. (4)

Fig. 6.—Narrowleaf Willow (*Salix exigua*). ×½.

| | |
|---|---|
| **2a.** Young twigs usually hairy; leaves firm. | **Salix lasiandra** Benth. "Western Black Willow" |
| **2b.** Young twigs smooth; leaves thin. | **Salix amygdaloides** Anders. "Peach Willow" |
| **3a.** Upper surface of leaves dark green; lower surface pale. | **Salix nuttallii** Sarg. "Nuttall's Willow" |
| **3b.** Upper surface of leaves pale; lower surface dull. | **Salix bebbiana** Sarg. "Bebb's Willow" |
| **4a.** Capsule glabrous when mature. | **Salix exigua** Nutt. "Narrowleaf Willow" |
| **4b.** Capsule densely white-silky, even when mature. | **Salix sessilifolia** Nutt. "Narrowleaf Willow" |

## Genus 8. **BETULA**, Birch

In addition to the two trees of this genus there is a dwarf shrub (*Betula glandulosa* Michx.) along streams at high altitudes.

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1a. Bark of trunk brownish-gray; fertile catkins about 15 mm. (⅝ in.) long.
**Betula fontinalis** Sarg.
"Canyon Birch"

1b. Bark of trunk pale gray or light brownish; fertile catkins about 30 mm. (1¼ in.) long.
**Betula andrewsii** A. Nels.
"Andrews' Birch"

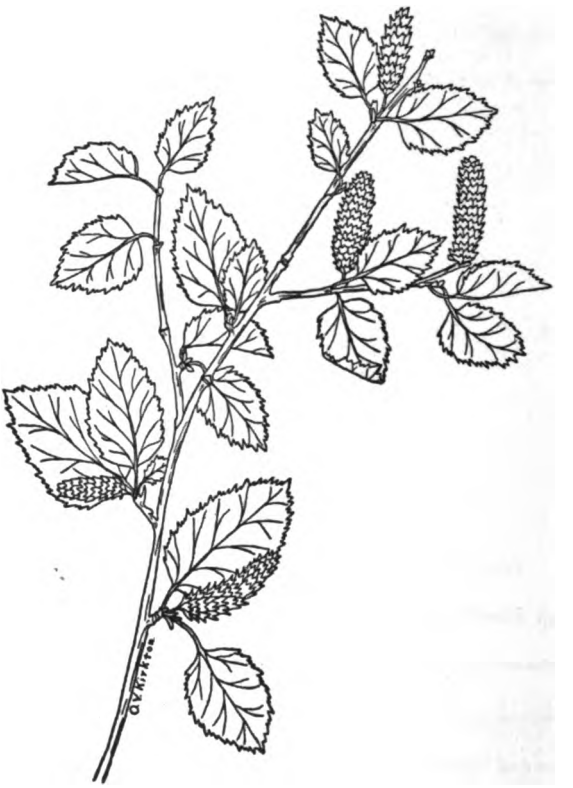

FIG. 7.—CANYON BIRCH (*Betula fontinalis*). ×½.

## Genus 9. **ALNUS,** ALDER

This genus is represented by a single species, a tree or shrub growing in clumps along streams. Leaves broadly ovate, doubly toothed.

**Alnus tenuifolia** Nutt.
"Alder"

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FIG. 8.—ALDER (*Alnus tenuifolia*). ×½.

## Genus 10. **QUERCUS**, OAK

Eleven species of oak are recorded by Rydberg as occurring in Colorado. They are found in the foothill districts at moderate altitudes, chiefly in the southern and western parts of the state. The following are the only trees.

**1a.** Leaves at maturity velvety beneath. **Quercus utahensis** (DC.) Rydb. "Utah Oak"

**1b.** Leaves at maturity smooth or downy but never velvety beneath. (2)

**2a.** Mature leaves very thin. **Quercus leptophylla** Rydb. "Colorado Oak"

**2b.** Mature leaves firm. (3)

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**3a.** Leaves ob-ovate in outline; cleft half-way to the mid-rib or less; acorns acute.
**Quercus gambellii** Nutt
"Gambell's Oak"

**3b.** Leaves ob-ovate in outline; cleft deeper than half-way to the mid-rib; acorns obtuse.
**Quercus nitescens** Rydb.
"Shining Oak"

FIG. 9.—SHINING OAK (*Quercus nitescens*). ×½.

## Genus 11. CELTIS, HACKBERRY

These trees have much the appearance of elms. The leaves are oblique at base and the trunk is rough and deeply furrowed.

**1a.** Leaves broadly ovate; acute or short pointed at apex; ripe fruit red.
**Celtis reticulata** Torr.
"Thick-leaved Hackberry"

**1b.** Leaves ovate, often long pointed at apex; ripe fruit black. **Celtis douglasii** Planch.
"Douglas Hackberry"

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FIG. 10.—THICK-LEAVED HACKBERRY (*Celtis recticulata*). ×½.

## Genus 12. CERCOCARPUS, MOUNTAIN MAHOGANY

In addition to the species named below there is a shrubby *Cercocarpus* which has dentate leaves; very abundant on the rock ridges and lower foothills east of the divide.

1a. Tree or shrub with very small entire leaves; fruit seed-like with long plumose tail. Found on the western slope of the Rocky Mountains. **Cercocarpus ledifolius** Nutt.

FIG. 11.—MOUNTAIN MAHOGANY (*Cercocarpus ledifolius*). ×½.

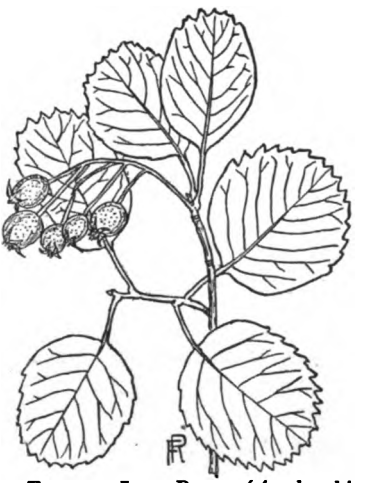

FIG. 12.—JUNE BERRY (*Amelanchier alnifolia*). ×½.

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## Genus 13. **AMELANCHIER,** JUNE BERRY, SERVICE BERRY

Seven species of this genus are recorded from the state, all but the following being shrubs.

**1a.** Small tree or shrub on hillsides or in canyons; the fruit a pome; leaves toothed only near the apex. **Amelanchier alnifolia** Nutt.

## Genus 14. **CRATAEGUS,** THORNAPPLE

Trees or shrubs with stout spines and handsome white flowers; growing along streams in the foothill region. Fruit, red, black, brown or orange. (See Figs. 13 to 18.)

FIG. 13.—COLORADO THORNAPPLE (*Crataegus coloradensis*). ×½.

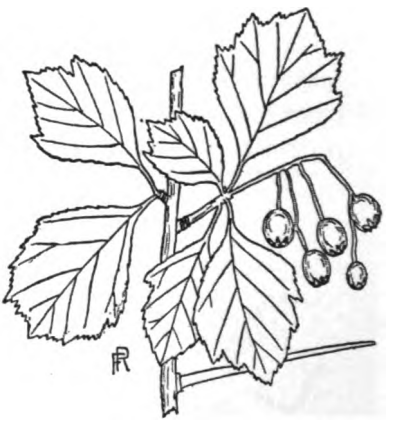

FIG 14.—ST. LAWRENCE THORNAPPLE (*Crataegus laurentiana*). ×½.

| | |
|---|---|
| **1a.** Spines long, 3 to 8 cm. (1½ to 3 in.). | (2) |
| **1b.** Spines short, about 2 cm. (¾ in.). | (7) |
| **2a.** Anthers pink or crimson. | (3) |
| **2b.** Anthers white or cream. | (4) |
| **3a.** Pedicels glabrous. | **Crataegus erythropoda** Ashe. "Shiny-leaved Thornapple" |
| **3b.** Pedicels somewhat villous; leaves broadly ovate. | **Crataegus coloradensis** A. Nels. "Colorado Thornapple" |

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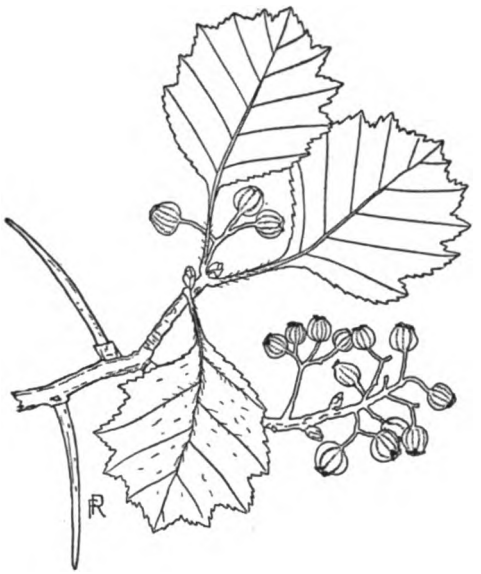

FIG. 15.—THICK-LEAVED THORNAPPLE (*Crataegus doddsii*). ×½.

FIG. 16.—CANYON THORNAPPLE (*Crataegus coloradoides*). ×½.

FIG. 17.—SMALL-LEAVED THORNAPPLE (*Crataegus saligna*). ×½.

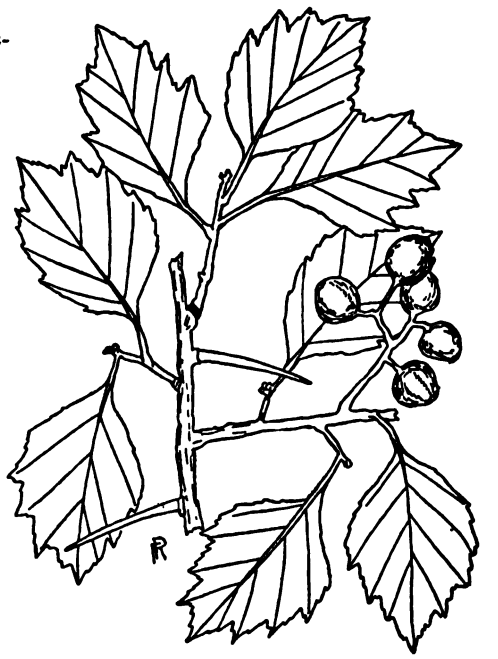

FIG. 18.—SHINY-LEAVED THORNAPPLE (*Crataegus erythropoda*). ×½.

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3c. Pedicels densely villous at flowering time; becoming nearly glabrous; leaves obovate, wedge-shaped at base. **Crataegus laurentiana** Sarg. "St. Lawrence Thornapple"

4a. Shoots becoming glabrous or nearly so at close of first year; leaf serrations glandular. (5)

4b. Shoots villous or pubescent throughout the first year; leaf serrations not glandular. (6)

5a. Leaves at maturity perfectly glabrous; fruit golden yellow.[1] **Crataegus chrysocarpa** Ashe. "Golden Thornapple"

5b. Leaves at maturity with scattered villous pubescence below, especially on the veins; fruit dark red. **Crataegus doddsii** Ramaley "Thick-leaved Thornapple"

6a. Petiole about ¼ the length of the blade; leaf-apex often obtuse. **Crataegus occidentalis** Britt. "Western Thornapple"

6b. Petiole about ⅓ to ½ the length of the blade; leaf-apex often somewhat truncate. **Crataegus coloradoides** Ramaley. "Canyon Thornapple"

7a. Leaves ovate, simply serrate or crenate, 2 to 4 cm. broad. **Crataegus rivularis** Nutt. "River-bank Thornapple"

7b. Leaves lanceolate, serrate, sometimes obscurely lobed; only 1 to 2 cm. broad (generally about 1.5 cm.) **Crataegus saligna** Greene "Small-leaved Thornapple"

## Genus 15. PRUNUS, PLUM AND CHERRY

Four species of *Prunus* are recognized as occurring in Colorado. One is the common wild plum so abundant at canyon mouths in the foothills; the others are cherries. Of the latter, *Prunus besseyi* is a dwarf species, often a mere trailing or prostrate shrub.

1a. Flowers and fruits in long racemes; fruit black when ripe. **Prunus melanocarpa** (A. Nels.) Rydb. "Choke Cherry"

1b. Flowers and fruits in short umbels or corymbs. (2)

2a. Leaves bright green and shining above; fruit red, 5 to 7 mm. (about ¼ in.). in diameter. **Prunus pennsylvanica** Linn. f. "Wild Red Cherry"

2b. Leaves dull green above; fruit 20 to 25 mm. (¾ to 1 in.) in diameter. **Prunus americana** Marsh. "Wild Plum"

[1] These characters are taken from the original description but do not agree with certain specimens credited to this species.

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FIG. 19.—WILD PLUM (*Prunus americana*). ×½.

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FIG. 20.—CHOKE CHERRY (*Prunus melanocarpa*). ×½.

## Genus 16. **ROBINIA,** LOCUST

The native Colorado locust is closely related to the common black locust or yellow locust now so often planted for posts and railway ties.

1a. Small tree or shrub with pinnately compound leaves and pink, pea-like flowers, producing many-seeded pods. Along streams in southern part of state.
**Robinia neo-mexicana** A. Gray.
"Pink Locust."

## Genus 17. **ACER,** MAPLES AND BOX-ELDER

1a. Leaves compound, of 3, 5 or 7 leaflets. **Acer interior** Britt.
"Box-Elder"

1b. Leaves simple; palmately veined. (2)

2a. Leaves longer than broad; generally three-lobed, margins distinctly serrate.
**Acer glabrum** Torr.
"Rocky Mountain Maple"

2b. Leaves broader than long; three to five-lobed; margins not serrate.
**Acer grandidentatum** Nutt.
"Mountain Sugar Maple"

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FIG. 21.—PINK LOCUST (*Robinia neo-mexicana*). ×⅓.

FIG. 22.—ROCKY MOUNTAIN MAPLE (*Acer glabrum*). ×⅓.

FIG. 23.—BOX ELDER (*Acer interior*). ×⅓.

FIG. 24.—SUMAC (*Rhus glabra*). ×⅓.

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## Genus 18. **RHUS,** SUMAC

This genus is represented in Colorado by *Rhus rydbergii*, the western poison ivy and *Rhus trilobata*,the common "skunk bush," in addition to the following species.

**1a.** Usually a shrub but often tree-like at canyon mouths in rich, well-watered soil. Leaves compound, of numerous pointed leaflets; turning to red or crimson in autumn.
**Rhus glabra** Linn.
"Sumac"

## Genus 19. **RHAMNUS,** BUCKTHORN

**1a.** Tree of western Colorado and westward; elliptical leaves; small greenish flowers; black berry-like fruits. The bark has medicinal properties.
**Rhamnus purshiana** DC.
"Cascara sagrada"

FIG. 25.—CASCARA SAGRADA) *Rhamnus purshiana*). ×½.

FIG. 26.—ASH (*Fraxinus anomala*). ×½.

## Genus 20. **FRAXINUS,** ASH

Related to the "white ash" and "green ash" so commonly planted for shade. The Colorado species has the typical flower and fruit structure of the ash but the leaf is not usually compound.

**1a.** Leaf simple, or occasionally with two or three leaflets; fruit a winged samara. Occurring in canyons of the southwestern part of the state.
**Fraxinus anomala** Torr.

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## ALPHABETICAL INDEX OF TREES

| | PAGE | | PAGE |
|---|---|---|---|
| Abies concolor | 263 | Crataegus chrysocarpa | 274 |
| lasiocarpa | 263 | coloradensis | 272 |
| Acer glabrum | 276 | coloradoides | 274 |
| grandidentatum | 276 | erythropoda | 272 |
| interior | 276 | doddsii | 274 |
| Alder | 268 | laurentiana | 274 |
| Alnus tenuifolia | 268 | occidentalis | 274 |
| Amelanchier alnifolia | 272 | rivularis | 274 |
| Ash | 278 | saligna | 274 |
| Aspen | 264 | Douglas spruce | 262 |
| Betula andrewsii | 268 | Cottonwood | 264 |
| fontinalis | 268 | Fir | 262 |
| Birch | 268 | Fraxinus anomala | 278 |
| Buckthorn | 278 | Hackberry | 270 |
| Cascara sagrada | 278 | Hawthorn | 272 |
| Cercocarpus ledifolius | 271 | Juniper | 263 |
| Cedar | 263 | Locust | 276 |
| Celtis douglasii | 270 | Maple | 276 |
| reticulata | 270 | Mountain mahogany | 271 |
| Colorado blue spruce | 261 | Oak | 269 |

Digitized by Google

| | PAGE |
|---|---|
| Picea engelmanni | 261 |
| parrayana | 261 |
| Pine | 259 |
| Pinus aristata | 259 |
| edulis | 260 |
| flexilis | 259 |
| murrayana | 260 |
| scopulorum | 260 |
| Poplar | 264 |
| Populus acuminata | 266 |
| angustifolia | 266 |
| balsamifera | 266 |
| sargentii | 264 |
| tremuloides | 264 |
| wislizeni | 264 |
| Prunus americana | 274 |
| melanocarpa | 274 |
| pennsylvanica | 274 |
| Pseudotsuga mucronata | 262 |
| Quaking aspen | 264 |
| Quercus gambelii | 269 |
| Quercus leptophylla | 269 |
| nitescens | 270 |
| utahensis | 269 |
| Rhamnus purshiana | 278 |
| Rhus glabra | 278 |
| Robinia neo-mexicana | 276 |
| Sabina monosperma | 264 |
| scopulorum | 264 |
| utahensis | 263 |
| Salix amygdaloides | 267 |
| bebbiana | 267 |
| exigua | 267 |
| lasiandra | 267 |
| nuttallii | 267 |
| sessilifolia | 267 |
| Silver spruce | 261 |
| Spruce | 261 |
| Sumac | 278 |
| Thorn | 272 |
| Thornapple | 272 |
| Willow | 267 |


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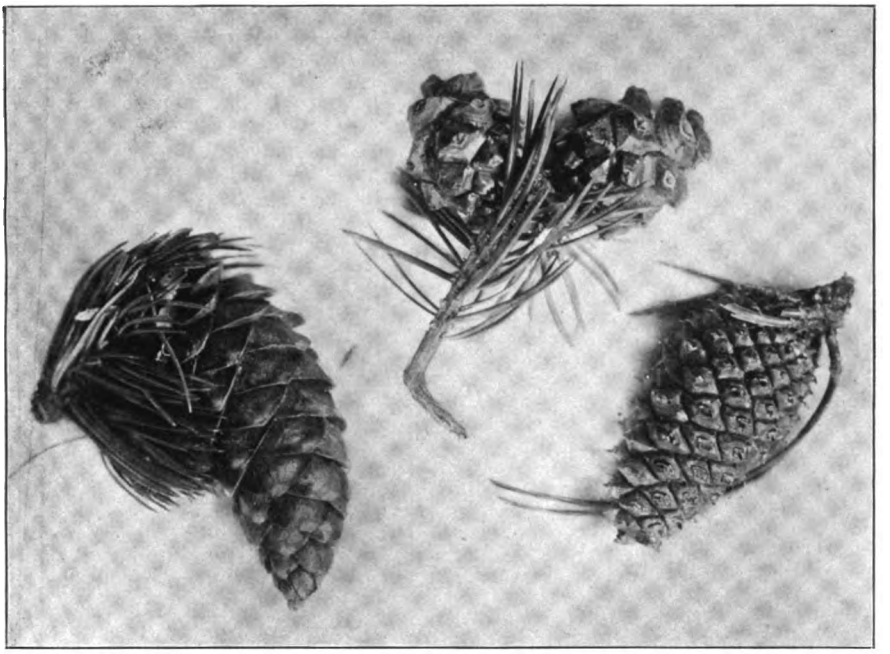
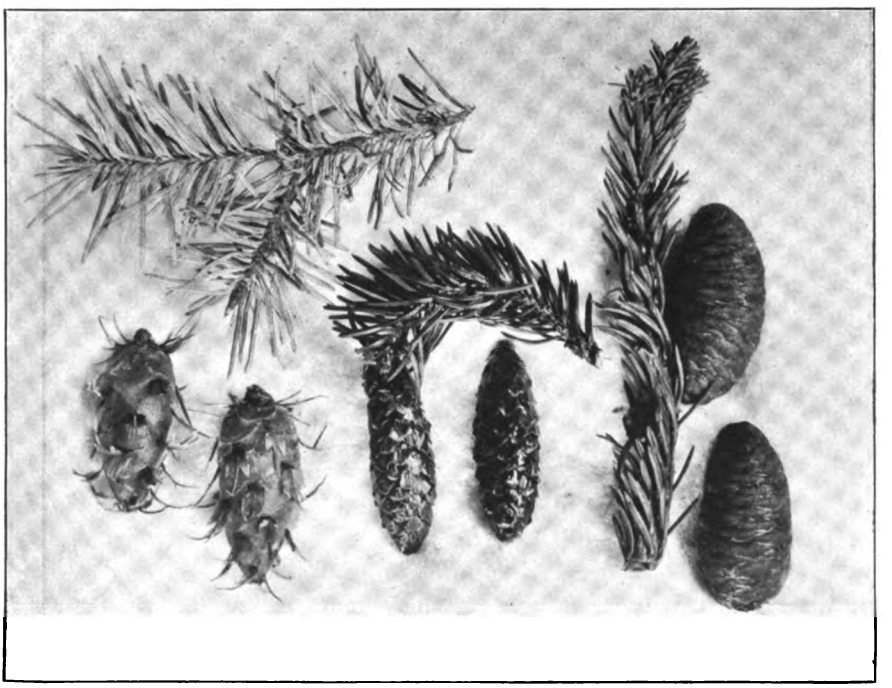


Limber Pine Pinyon Pine Rock Pine

FIG. 27.—Pines. $\times \frac{2}{3}$



Douglas Spruce Engelmann Spruce Sub-Alpine Fir

FIG. 28.– Spruces and Fir. $\times \frac{2}{3}$



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FIG. 29.—Sub-Alpine Scrub at Timberline.

FIG. 30.—Sub-Alpine Forest of Engelmann Spruce



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FIG. 31.—Limber Pine near Pawnee Buttes, Colo. This is the most eastward extension of its range.

FIG. 32.—Colorado Blue Spruce



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FIG. 33.—Rock Pines. Lower limit of tree growth on mesas and foothills. Young sumacs in the foreground. Late winter.

FIG. 34.—Rock Pine



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# CONTENTS

PAGE

1. FOREIGN DRAMA ON THE ENGLISH AND AMERICAN STAGE. I. FRENCH DRAMA . . . . . 287
CHARLES C. AYER, PH.D.
Professor of Romance Languages

2. ORGAN TRANSCRIPTIONS . . . . . 299
GEORGE M. CHADWICK
Professor of Music

3. NOTES ON PROTOZOA . . . . . 305
T. D. A. COCKERELL
Professor of Systematic Zoölogy

4. A FOSSIL GROUND-SLOTH IN COLORADO . . . . . 309
T. D. A. COCKERELL
Professor of Systematic Zoölogy

5. NOTE ON THE HEATING EFFECTS IN METALS PRODUCED BY BOMBARDMENT WITH KATHODE RAYS . . . . . 313
OLIVER C. LESTER, PH.D.
Professor of Physics

6. ALPHABETICAL INDEX TO VOLUME VI . . . . . 317

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# FOREIGN DRAMA ON THE ENGLISH AND AMERICAN STAGE

## I. FRENCH DRAMA

By Charles C. Ayer

The object of the present paper is to trace the course of the French drama on the English and American stage, as it appears to us in translations and adaptations. Most Americans at the present day enjoy the theater and derive a keen pleasure from watching a good play from a comfortable seat of a modern theater, but not all, in the excitement of the moment, are interested in the origin of the play. "The play's the thing," and if it be a good one in the popular sense, it is pleasantly remembered in the form in which it was presented. Nevertheless it may have traveled far and undergone many changes, since it left its original author's pen. The programs of the present day, even in university towns, often omit the name of the author as being of no consequence, though to the enthusiastic playgoer and student of the drama, the name of the author is often what induces him to go to see the play. Indeed, the author's name and the nationality of a play are of prime importance to him. If these two elements are lost sight of, we cannot follow any play with full intelligence. Nor can we realize the great debt which we owe to foreign nations and especially to France as one of the foremost purveyors to the theater. Nevertheless, some of the best-known plays on the American stage are of French origin. Let us see how and when they came into existence.

The theater in France, as every student knows, originated as it did elsewhere, in the church. During the Middle Ages the serious drama was represented in the form of miracles, mysteries and moralities, the purpose being religious, ethical and didactic. The comic drama was represented by moralities, farces and sotties, and produced by the guilds of the times, amateur associations of artisans. But with the dramatic output of France in the Middle Ages we have nothing to do from the present point of view, though we come very near to the spirit



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of it in the English morality play *Everyman*, of the same period, which has been so splendidly given in the past few years by the Ben Greet Players.

The real French drama is regarded as beginning with the year 1552, when Jodelle wrote his *Cléopâtre*, the first classic French tragedy, a work which naturally met with the approval of the author's associates in the Pléiade. Jodelle's *Cléopâtre*, however, is only a literary milestone, and the Egyptian queen's appearance on the American stage by way of France did not take place until about twenty years ago in Sardou's drama of that name (1890).

Passing on from 1552, the next important date in the development of the French drama is 1636, the year of Corneille's *Cid*, one of the glories of French literature, though it in no way affects our twentieth-century English stage. The year 1636 merely marks in France the beginning of the hard-and-fast application of the rule of the three unities, a rule which lasted practically unchallenged up to the date of Victor Hugo's *Hernani* (1827).

For nearly two hundred years, during the literary activity of Molière, Corneille, Racine and Voltaire, all well-known names in the history of the world's literature, the French classic drama flourished, and yet we find no trace of it in England or the United States at the present time. If one reads carefully the latest copy of the *New York Dramatic Mirror* he will look in vain for the French drama of the age of Louis XIV in the repertory of England, the United States, Australia and South Africa. One recent exception, however, should be noted. In the season of 1905–6 the late Richard Mansfield made a notable production of Molière's *Misanthrope* (1666). The performances of this piece were, however, limited to a few of the larger cities where there is a cultivated public. Mr. Mansfield himself regarded it more as a literary and artistic offering than as a response to a popular demand. His attitude was quite that of the Donald Robertson Players of Chicago, who under the auspices of the Chicago Art Institute are now producing periodically before select audiences the masterpieces of the world's dramatic literature in English translation, among others the works of Molière, and in view of the amazing brilliancy and vitality of Molière's plays, it

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is surprising that none of them is known on the regular stage. In Germany *Les précieuses ridicules* (1659) and *Le malade imaginaire* (1673) are frequently given in the municipal theaters.

If the golden age of French literature has bequeathed us practically nothing, the eighteenth century has done no better. It is not until the nineteenth century that we begin to draw plays from France as from an unfailing source. Strangely enough the *Hernani* of Victor Hugo seems to have had no career on the American stage, though its memorable production in 1827 made its author the foremost poet-dramatist of his time. No mention of *Hernani* is to be found in the old programs of Booth, Salvini, Forrest and other actors who would have been likely to give the play. On the other hand, Victor Hugo's *Ruy Blas* (1838) is well known to American playgoers. Edwin Booth was a famous *Ruy Blas* in his younger days, the last actor of distinction to play the part being Alexander Salvini. With his death in 1893 the play has vanished, at least temporarily, from the American stage, though when the right romantic actor appears we may look for a revival of what is without doubt Hugo's dramatic masterpiece. Hugo's other dramas remain unknown to us in English versions, though two of them, *Hernani* and *Le roi s'amuse*, have furnished the plots for well-known Italian operas, the *Ernani* (1844) and *Rigoletto* (1851) of Verdi. On the whole, the romantic drama of Victor Hugo seems not to have held its own very well, even in Paris. *Hernani*, *Ruy Blas*, and *Le roi s'amuse* are all that are now retained in the repertory of the Theâtre Français. The revival of *Angelo* (1835) a few seasons ago was a failure in spite of the fine acting of Mme. Sarah Bernhardt.

A few years after the heyday of Hugo's dramatic fame, we meet with an author whose name and plays are well known to American theater-goers. Though famous chiefly as a writer of romances and stirring historical novels Alexandre Dumas the elder (1806–70) has contributed plays to the stage which still possess great drawing powers. First and foremost must be mentioned *Monte Christo*, which, though dating from 1848, is still being presented as for the past thirty years by Mr. James O'Neill. This record may fairly be said to rank with that of the late Joseph Jefferson in *Rip Van Winkle* or Kate Claxton in

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*The Two Orphans*. Times may have changed and the taste of the public may have experienced many different phases since 1848, but Mr. O'Neill still possesses the art to charm in *Monte Christo*. A few years ago another of Dumas' novels, turned into a play, experienced a new lease of life—*The Three Guardsmen* (1844) in various versions was given all over the country. Of the better-known actors identified with this revival were Mr. E. H. Sothern in America and Mrs. Potter in London.

Simultaneously with Victor Hugo and Dumas, a very prolific author was at work who has furnished the English stage with several plays. This was Eugene Scribe (1791–1861). His most famous play is, perhaps, *Adrienne Lecouvreur* (1849), originally written for Rachel, which has long been a favorite one with emotional actresses of all nations. Mme. Bernhardt and Mme. Modjeska, to mention only two, are among the most distinguished representatives of the heroine seen in this country. Miss Olga Nethersole is the most recent interpreter of the rôle. Another play of Scribe, *La bataille de dames* (1851), in the admirable translation of Charles Reade, was in the repertory of Mme. Modjeska some six or seven years ago. Scribe was also the author of many light and grand-opera librettos, many of which have been sung in English. The best known of these operas are Flotow's *Martha* (1847), Auber's *Fra Diavolo* (1830), and *Crown Diamonds* (1831), Halévy's *The Jewess* (1855), Donizetti's *Elixir of Love* (1832), and Meyerbeer's *Robert the Devil* (1831), *The Huguenots* (1836), *The Prophet* (1849) and *L'Africaine* (1864). Scribe wrote over four hundred dramatic pieces, and it is probable that the germs of these are to be found scattered throughout the dramatic literature of many nations. Much of his work is of very slight value, even if he was a member of the Academy, but taken together, it entitles him to an important place in the development of the French drama. His apparently trivial *comédie-vaudevilles*, like *The Loan of a Lover*, are still full of quaint, old-fashioned charm, when given, as they often are, by amateur dramatic societies.

We now come to a dramatic author whose work is practically unknown on the American stage, Emile Augier (1820–89). His *Gendre de M. Poirier* (1855) is, to be sure, known to many a student of French in

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college, and in English translation it has been performed within recent years in Chicago under semi-amateur, "hole-in-the-wall" auspices. But the great public knows nothing of him, though he is ranked at home among the foremost French dramatists. Back in 1855 he produced a play, *Le mariage d'Olympe*, which was intended as a protest against the success of Dumas' *Camille*, a protest against the sentimentality of Dumas' rehabilitation of the fallen Marguerite Gautier. In Augier's play the heroine, Olympe, though temporarily reclaimed by marriage into a respectable family, nevertheless falls back into her past life, for the reason that she was at heart common, brazen, and not repentant nor desirous of rehabilitation. The father of the young man who has married her finally shoots her dead and the curtain falls on an unnecessarily violent ending, which leaves the spectator not only horrified but dissatisfied. It may be that Augier, otherwise an author of moderation and poise, made his *Mariage d'Olympe* as revolting as possible in order to emphasize his disapproval of the success which Dumas' play had attained three years before, in 1852. In *La dame aux Camélias*, Dumas had endeavored to show the complete repentance and rehabilitation of his heroine through a pure love. But it will be remembered that she dies in the last act, and, therefore does not marry Armand and enter into the Duval family. Augier in his play took up the thread where Dumas left off, and carried the idea through. He did not beg the question, but faced his problem, a real problem, and settled the fate of his heroine, as fearlessly and logically as Pinero settled the fate of "The Second Mrs. Tanquary" some forty years later. In view of the fact that *Le mariage d'Olympe* is a genuine problem play and an interesting and well-constructed one, it is surprising that in this day of problem plays, Mr. Clyde Fitch's adaptation of it a few years ago under the title, *The Marriage Game*, met with no success, but neither his skilful stagecraft nor the interesting personality of Miss Sadie Martinot, for whom he adapted the piece, could keep the play long before the public. It soon disappeared, whereas *Camille* is still with us, and continues to be, as it always has been, the most popular and famous play that has come to us from France. This is not saying that it is to be ranked in merit with the *Cid* of Corneille, the *Phèdre*

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of Racine or the *Misanthrope* of Molière, nor with many another of the ornaments of the French drama, but it is the play which has claimed the attention of the greatest emotional actresses at home and abroad. It is as well known in Germany and Italy as it is in France. In their tours of the United States, it is still the *pièce de résistance* of Sarah Bernhardt and Eleonora Dusé. The story is so well known that it matters little what language it is played in. In the United States it was in *Camille* that Mme. Modjeska first appeared in 1877. Miss Clara Morris was for years a famous Camille. Among the most recent interpreters of the rôle are Miss Olga Nethersole and Miss Margaret Anglin. In many quarters *Camille* has doubtless run its course. The critics already pronounce it old fashioned and sentimental, as it doubtless is in parts, but the emotional opportunities which it offers, are likely to appeal to leading ladies for a long time to come. It still compels a tribute of tears from the women in the matinee audiences, and the success of an emotional actress or an emotional play is very largely measured in terms of tears.

Following *Camille* Alexandre Dumas the younger (1824–95) wrote many plays with a purpose, several of which may still be remembered by the present generation of playgoers. In 1893 *Le demimonde* (1855) was produced in the United States in two versions, *The Crust of Society* and *The Fringe of Society*. Mr. John Drew appeared for a time in *The Squire of Dames* (*L'ami des femmes*, 1864), and Dumas' last play, *Francillon*, from the year 1887 was produced by Mrs. Potter under the title, *A Wife's Peril*. But for the past ten years these plays have not been before the public. They ran their course as novelties, but now seem as remote as *The Danicheffs* (1875), a powerful and successful drama in which Dumas collaborated, and which in the 70's was one of the record-breaking successes of the old Union Square Theater in New York. On the whole, then, Alexandre Dumas the younger is, from our present point of view, a man of one play. But *Camille* has made him immortal.

The best-known French name to the present day theater-goers in this country is that of Victorien Sardou (1831–1908), whose recent death the French are still mourning. His first appearance as a dramatist was

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in 1861, the year of Scribe's death. Since that time and up to within a very few years of his death, Sardou continued to turn out plays, which won him fortune at least and a goodly amount of well-deserved fame. His best-known play in America and England, *Les pattes de mouche*, dates from the year 1861. Under the title, *A Scrap of Paper*, it belongs to the best traditions of Wallack's Theater and the Boston Museum. It attracted attention anew in 1889 as one of the most pleasing plays offered by Mr. and Mrs. W. H. Kendal on the occasion of their first tour in the United States. A few years ago a new version of this play was presented by Miss Henrietta Crosman under the title, *Mary, Mary, Quite Contrary*. Another excellent play of Sardou is *Dora*, written in 1877, and known in English as *Diplomacy*. Still another, in quite a different vein from those just mentioned, is *Divorçons* (1880), a brilliant, gay and frivolous treatment of the divorce question. This comedy, which is in the repertory of Mrs. Minnie Maddern Fiske, has for the past two seasons been given a model revival by Miss Grace George. It bids fair to outlast the series of sensational semi-historical plays with which Sardou's name is most closely associated, *Fédora* (1882), *Théodora* (1884), *La Tosca* (1887), and *Cleopatra* (1890), plays that were originally written for Mme. Sarah Bernhardt, and were afterward translated into English and produced by the late Fanny Davenport. After the death of the latter in 1897 they became the property of her husband, Mr. Melbourne McDowell, who still continues to play them. The most distinguished successor of Miss Davenport in the leading female rôles has been Miss Blanche Walsh.

In 1893 Sardou attained great success with his *Madame Sans Gêne*, a historical play based on an incident in the life of Napoleon the First. It is one of Sardou's strongest works and is not destined to be forgotten. Nevertheless it did not meet with favor in London, though it was played there by Sir Henry Irving and Miss Ellen Terry. In this country the play itself was well received and Miss Katherine Kidder as Madame Sans Gêne achieved the greatest success of her career.

Two of Sardou's last plays were given superb productions in America, *The Sorceress* (1904) by Mrs. Patrick Campbell and *Dante* (1903) by the late Sir Henry Irving during his last visit to this country.

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Octave Feuillet (1821–90) is a dramatist who has furnished the American stage with several interesting plays of varying character. His *Romance of a Poor Young Man,* written in 1858, was successful both as novel and as play. It is a French work which enjoys the comparatively rare distinction of being harmless enough for perusal in young ladies' boarding-schools. At the Boston Museum it enjoyed great popularity back in the 70's as did another play of Feuillet, *La tentation* (1860), translated by Dion Boucicault under the title of *Led Astray.* At the present time, however, Feuillet interests us chiefly as being the author of *A Parisian Romance* (*L'histoire d'une parisienne,* 1881), in which the late Richard Mansfield gave one of the most famous of his gruesome character impersonations in the part of the dissolute Baron Chévrial. *A Parisian Romance* is now to be seen in the stock company playhouses throughout the country.

The name of Eugène Labiche (1815–88) is famous in France for the many jolly evenings at the theater which it calls up. His work was rapid, light, gay and voluminous, but all that we know of it is his *Voyage de Monsieur Perrichon* (1860), which as *Papa Perrichon* was in the repertory of the Boston Museum in the late 70's, in the days of William Warren and Mrs. Vincent. A few seasons ago Mr. Clyde Fitch readapted and Americanized it under the title of *Cousin Billy* for Mr. Francis Wilson.

Likewise the names of Henri Meilhac (1831–97) and Ludovic Halévy (1834–1908) recall to our minds not only the brilliancy of their librettos, but also the captivating music of the *opéra-bouffes* of Offenbach and Lecocq. When we sit through an evening of dreary twaddle at one of our modern American musical comedies, we wonder how long it is to be before we have librettists worthy of the name, librettists worthy to collaborate with such composers as Victor Herbert and Reginald De Koven. To be sure we can scarcely hope to have another genius like W. S. Gilbert. The unique and glorious work of Gilbert and Sullivan is done. Furthermore, at present we seem incapable of lending dignity to frivolity. It was this delicate and elusive gift which enabled Meilhac and Halévy, though members of the august French Academy, to write the texts to *Orpheus and Eurydice* (1861), *La belle Hélène* (1865), *Blue*

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*Beard* (1866), *The Grand Duchess* (1867) and *The Little Duke* (1878). Having finished these light and frothy trifles they turned their attention to serious work by adapting the libretto of Bizet's immortal opera *Carmen* (1876) from Mérimée's novel of the same name. The work of a librettist is at the best rather thankless. The names of Meilhac and Halévy were submerged under the names of the composers for whom they purveyed. But they came into their own in at least one important play which is as well known in America as it is in France. This play is *Frou Frou* (1869), a sort of French *Doll's House*, and it has long been a favorite with leading actresses. Mme. Bernhardt and Mme. Modjeska have both been seen repeatedly as Frou Frou.

Emile Zola (1840–1902), whose fame as an author will always rest on his naturalistic novels, is known on the English stage by only two plays, one a dramatization of his novel *L'Assommoir* (1876), under the title *Drink*, a powerful drama first presented in this country in the 70's at the Boston Theater, and a few years ago revived by the eminent English actor, Mr. Charles Warner; the other an original and gruesome play, *Thérèse Raquin* (1867), which was at one time in the repertory of Mrs. Potter, and has recently been played by Mme. Bertha Kalich.

There are other French dramatists whose work is known in English form on the American stage. Among these is Adolphe d'Ennery (1811–99), whose drama *The Two Orphans* (1875), written in collaboration with Dumanoir, is one of the record-breakers of all time. The name of Miss Kate Claxton will always be associated with the rôle of the blind girl, Louise. Another play of D'Ennery, *Don César de Bazan* (1845), offered fine scope for the romantic acting of Edwin Booth and Alexander Salvini.

The name of Alphonse Daudet (1840–97) is known on the American stage through only one play, *Sappho* (1884), and this in a version prepared by Mr. Clyde Fitch, which means that the play is more Fitch than Daudet. Some years ago, Miss Olga Nethersole, aided by the yellow press, achieved great success in it, and it is still one of the most effective plays in her *répertoire*. It has also found its way into many of the stock-company theaters. In the original French version the title-rôle was played by Mme. Jane Hading and Mme. Réjane.

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George Ohnet is well known for his novel and drama, *Le Maître de forges*, known in English as *Claire and the Forge Master* and as *The Iron Master*, this last title being the one used by Mr. and Mrs. Kendal.

Alexandre Bisson is known to us through having furnished Daly's Theater with one of its conspicuous successes. Out of his *Surprises du divorce* (1888) came the graceful and diverting *Railroad of Love*, which was so delightfully given at Daly's in the days of John Drew, Ada Rehan, James Lewis and Mrs. Gilbert.

The most conspicuous French success of modern times is Edmond Rostand's *Cyrano de Bergerac*, produced in Paris in 1897 with Coquelin in the title-rôle and soon after in the United States with Richard Mansfield as Cyrano. Also *L'Aiglon* (1900) by the same author must be accounted a success, though this may be in part attributed to the prestige of the actresses who assumed the pathetic rôle of the young Napoleon, Mme. Bernhardt in Paris, and Miss Maude Adams in the United States.

Soon after *Cyrano de Bergerac* a French play was produced on the American stage, a play which apparently has come to stay. This is *Zaza* (1899), by Pierre Berton and Charles Simon. While *Cyrano de Bergerac* with its romantic atmosphere and true poetry appealed especially to the more literary class of theater-goers, *Zaza*, with its generally unwholesome character, at once commanded an interest and attention which show no signs of flagging. Without doubt much of the original success of *Zaza* was due to the extraordinary, nervous, emotional acting of Mrs. Leslie Carter. But the play is a strong one in itself. Mme. Réjane has made much out of the rôle of Zaza, and the play is now well known in the stock-company theaters from one end of the United States to the other. The story of Zaza has also inspired Leoncavallo to write an Italian opera. And even Mimi Aguglia, whose peculiar talents are supposed to be seen at their best in realistic Sicilian plays, has recently taken up the part of Zaza.

The name of Paul Hervieu is known to us through his psychological dramas, *Le dédale* (1903) and *Le réveil* (1905). Under the respective titles, *The Labyrinth* and *The Awakening*, they have been given fine productions by Miss Olga Nethersole.

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Henri Lavedan is the author of *The Duel* (1905), produced in this country by Mr. Otis Skinner. Octave Mirbeau is the author of *Les affaires sont les affaires* (1903), played by Mr. W. H. Crane. Henri Bernstein has two recent successes to his credit, *The Thief* (1906), played by Mr. Kyrle Bellew and Miss Margaret Illington, and *Samson* (1907), the feature of Mr. William Gillette's present season.

Doubtless in the foregoing pages, many plays have not been mentioned which in their day may have been put before the American public, and have achieved a temporary success, owing to temporary conditions or the popularity of the players. Such, for instance, was *The Daughter of Roland* (1875) of Henri de Bornier (1825–1901), as interpreted thirty years ago by the stately Mary Anderson or *Fanchon the Cricket*, adapted from George Sand's *La petite Fadette* (1849) and played for years by the sprightly Maggie Mitchell. This last play is still to be met with in the repertory of the more remote stock companies, and it must be admitted that it does have a charm of its own apart from that which must have been lent to it by the acting of Maggie Mitchell. It is hardly possible to say as much for the latest successful French play adapted for the American stage, *L'amour veille* (1907), which, under the title, *Love Watches*, has been one of the great successes of the present season in New York. This comedy by R. de Flers and A. Caillavet furnishes a pleasant evening's diversion, it is true, but this is chiefly owing to the rare personality and piquant acting of Miss Billie Burke as the heroine.

On the whole, then, if every French play that makes its way across the Atlantic does not prove to be a masterpiece with enduring life, we must admit that we owe to France a great debt for the many that we have received. Certain it is that English and American managers are watching the Parisian stage with eagerness in the present, as they have done in the past, and we may confidently expect to receive in the future the good things which are undoubtedly in store for us.

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# ORGAN TRANSCRIPTIONS

By George M. Chadwick

The subject of organ transcriptions (arrangements for the organ of compositions not originally composed for it) has always been open to discussion. As a rule conservative musicians have been opposed to admitting into organ literature compositions that are not strictly organ works. This position, though in some instances too pedantic, can in a measure be explained as a wise protest against the modern tendency to transcribe almost everything within sight, without any discrimination or sense of the eternal fitness of things. Such a state of affairs may well excuse conservative musicians from recognizing any compromise with the undeniable superficiality of that class of organists who seem to possess no innate understanding of the true nature of the organ, and are willing to give the public what it asks for—or rather what they assume to know that the public wants—without any anxiety about the state of their own musical consciences. Unfortunately there is an almost total absence of authoritative literature on this subject, which, by taking a comprehensive view of the entire range of composition, and by allowing for diversities of national temperament and the varying conditions which have at different times influenced organists and composers, can be considered as leading to a better understanding of the matter. This paper is merely an attempt to define some phases of the discussion and possibly to explain why there exists misunderstandings.

It is unfortunately true that since Bach and Handel, almost nothing has been written by the greatest composers for the organ as a solo instrument. The most important exceptions to this statement are Mendelssohn's Preludes and Fugues, his Organ Sonatas, Schumann's Canons, and also his Fugues on the name of Bach, and finally the eleven beautiful and noble Choral-Preludes which Brahms composed in the evening of his life—a worthy tribute to the organ, revealing again to the world its rich inexhaustible possibilities. But alas, how small



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in quantity is the above list of works when compared with the other instrumental compositions of the masters!

Hence there are two questions one may well ask. Why did not the composers of the latter half of the eighteenth and first half of the nineteenth centuries write more for the organ? And since they did not, shall organists be condemned for resorting to transcriptions rather than omit from their *répertoire* the greatest composers of that period? Possibly the first of these questions can be answered as follows: The composers of that period were less closely identified with the organ than were Bach and Handel, one reason being the development of the orchestra and the evolution of the piano from the clavichord and harpsichord to the modern instrument. It would require an exhaustive article on this alone to explain satisfactorily this neglect of the organ by the great composers for almost a century. I merely add this suggestion that had the organs of that period been more distinctly solo instruments in the modern sense, the case might have been otherwise. However magnificently some of those old organs could interpret a fugue, their clumsy mechanism and limitations in the matter of fine tonal shadings and contrasts did not invite the creation of new forms, such as the modern sonata. In fact, one feels that by common consent the composers recognized that nothing more could be written after Bach. When Mendelssohn at last broke the silence and gave to the world his own organ compositions, so beautiful and perfect, he sounded a prophetic note almost revolutionary in its full meaning—certainly revolutionary for Mendelssohn.

The second of these questions we can only hope to discuss and leave unanswered. The transition from the organ style of the early part of the eighteenth century to that of the orchestra must be considered from two standpoints—the difference between the organ and orchestra as a medium of musical expression, and those outward influences already exerting a force in the compositions of Bach's son, Carl Philipp Emanuel—influences of court life amounting to almost a reaction against the profound musicianship and earnestness of Bach. This is not the place to discuss the evolution of this style from the early symphonies of Haydn to its full development in Beethoven. A musician

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feels that as in the realm of organ tone the fugue rules supreme, so in that of the orchestra the eternal rightness of the symphony must be recognized.

But who shall say that there exists an impassable boundary-line which neither the organ nor orchestra can cross? If, for example, musicians welcome a Bach fugue arranged for the orchestra, why not accept at least a few movements from Beethoven's symphonies arranged for the organ? While it is true that the symphony loses much in being thus transferred from the orchestra to the organ, it is also true that it is not in every respect a gain to the organ fugue to be transferred to the orchestra. But the logical argument is after all based on the fact that the orchestra is hungry for a Bach literature, which it possesses only in a limited sense, unless orchestral arrangements are resorted to; and for the same reason the organists' hunger for a Beethoven literature can only be satisfied by transcriptions. While the mistakes of organists are many, not only in attempting at times the impossible—to say nothing of their often most unworthy interpretations of orchestral works—yet the motive is not an unworthy one when prompted and guided by true musicianship. And again, one must not forget that some of the greatest composers were organists, in some cases preferring the organ to any other instrument. Take, for example, Beethoven. One hardly thinks of him as playing exclusively the fugues, etc., of the early period of Bach's time, but rather as finding through the medium of the organ an expression for his creative energy—in other words as improvising. Now, while we have no exact record of these improvisations, we can imagine the same Beethoven at the organ that we know in his sonatas, quartettes and symphonies. We cannot know what he dreamed at the organ. Perhaps at the sacrifice of some of the immortal works he has left to the world he might have enriched organ literature. But this is only dreaming of what might have been.

Let us now turn to the more technical questions, explaining also some of the limitations of the organ and also why transcriptions are either justly or unjustly criticized. A subject of vital importance in this connection is that of registration (the use of organ stops). While the possibilities of an organ to reproduce approximately certain orchestral

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effects vary according to the size, specifications and voicing of different organs, nevertheless, even in the case of the largest ones, the limit of these effects is soon reached. One reason is that none of the orchestral-toned stops can rival in expression, intensity or volume either the massing of these tone qualities in the orchestra, or even of the individual instruments; hence this reproduction of orchestral tone color is after all only in miniature, the more so as it passes from very soft passages to the full power of the orchestra. Another very apparent limitation is in the matter of *crescendo* and *diminuendo*, for the adding or subtracting of stops alters the tone quality, and in the majority of organs these effects obtained by means of swell pedals cannot be compared with those of the orchestra. Nor is this all, for when the organist passes from these orchestral tones to the diapason and other stops which belong alone to the organ and have no counterpart in the orchestra, the ear is at once disillusioned, and one awakens to the fact that after all the organ is noblest when asserting its own individuality. This transition is a severe test of an organist's musicianship. I have heard organists fail so utterly in this that I almost doubted their ever having heard an orchestra. What is said above relative to the limitations of the organ may seem like a contradiction of the following from the pen of that eminent organist and musician, Ch. M. Widor:

> Cavaillé-Coll's instruments, with their admirable tones and their incomparable mechanism, have attracted and passionately interested a number of composers, who have found in them a genuine orchestra, varied, supple, and powerful, respectful of tradition, yet ready to welcome a new ideal.

M. Widor's ideal is Bach, and the ideal of the master organ builder to whom he refers, was to unveil through his wonderful organs "the colossal work of the Master of Eisenach, of hearing Bach as he wished to be heard." When M. Widor speaks of finding in them a "genuine orchestra," he is not referring to the orchestra itself but rather to those possibilities in the realm of organ tone *as organ tone* which in themselves constitute an orchestra with its own individuality.

In playing transcriptions one of two methods can be followed: one to remain within the limitations of these orchestral effects, and the other to translate freely into organ tone the orchestral composition. In some

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compositions it would be better to adhere strictly to one or the other of these plans, while in others the advantage and even necessity of combining them would be apparent. When one hears an organist play the opening theme from the Pilgrim's Chorus from *Tannhäuser* on a *vox humana* stop in a *tempo rubato* style, one wishes there was an international law consigning all such offenders to exile on some far-away island—offenders to be found in the ranks of organists who consider themselves musicians and who hold good positions even in large cities. This is but one of many illustrations of compositions where the organ reproduces, or at least suggests, the orchestral effects, and where any failure to interpret the true spirit of the composition is utterly unpardonable. In the case of Beethoven's "Coriolanus" overture a free translation on the organ is much better than an attempt to follow the score, for thus interpreted it becomes a noble organ composition—one can almost think that had Beethoven written for the organ he would have composed for it a "Coriolanus" overture.

It is interesting to note the attitude of the German, French and English organists in this matter—an attitude influenced by national temperament, often by local conditions, and most certainly by the demands of the church. The conservative musicianship of Germany and France has prevented many serious mistakes; but in England there has been less opposition. While the masterly transcriptions of W. T. Best and a few since are worthy additions to organ literature, unquestionably the mania for transcribing has been allowed to run riot and, especially in America, those organists who so far forget the nature of their instrument as to attempt almost everything in piano literature from Mendelssohn's "Spring Song" to the Rhapsodies of Liszt—to say nothing of their devouring hunger for orchestral works—deserve severe criticism. Granting there are temptations in this country to make concessions to a public taste which is far from an understanding of the true organ style, either in composition or performance, and that the organ is too often considered as a concert instrument with no reference to its proper architectural environment, it is still the duty of the organist to remain true to certain ideals, and not to degrade his noble art merely to flatter superficial public taste for selfish personal reasons.

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In closing I may be allowed to say that much that I have written above was included in a "round table" discussion of organists held at Saratoga, N. Y., in 1900. Among those present were several eminent organists from New York City. Their enthusiastic support of my argument and my own experience during the succeeding years have caused me to maintain with only slight modifications the views I then held. As to piano compositions being played on the organ, they are only satisfactory when by their nature they suggest the organ or orchestra. A long list of such could be made and would be interesting and valuable. Sometimes even a beautiful lyric theme, apparently only suited to the piano, can be most exquisitely interpreted. And again I have in mind Rubinstein's "Hermit" (from *Twelve Piano Sketches*) which, played on a large organ containing a fine 32-ft. Bourdon in the pedal and soft 16-ft. string and reed stops in the swell, can be interpreted n a manner far nobler than on the piano. It is possibly less excusable to transcribe songs, violin and other solos, for soloists are usually available even in small cities. Arrangements of choruses, particularly from oratorios and masses, can hardly be objected to, as they are in the original so closely identified with the organ. All transcriptions, especially orchestral, are a severe test of an organist's musicianship. Only one who is a broadly educated musician as well as a master of the technique of his instrument can worthily approach an orchestral work, for the technical difficulties—often almost insurmountable, must have become incidental to such an extent that his imagination is not cramped by the limitations of his instrument. He must be for the time being not only an organist, he must be a director exerting, not over a body of orchestral musicians but over his own other self, so to speak, that concentrated energy of will power and musical personality that is essential to the director of a symphony orchestra.

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# NOTES ON PROTOZOA

By T. D. A. Cockerell

In my paper on "Boulder Protozoa" in these *Studies* (Vol. IV, No. 4, pp. 261–64, 1907), I most unfortunately overlooked Dr. E. Penard's very important paper in the *American Naturalist*, December, 1891, pp. 1070–83, entitled "Rocky Mountain Rhizopods." In this paper are listed from the mountains of Boulder County 35 species and two varieties of Rhizopods, and also two Cilioflagellata and three Heliozoa. One species (*Diffugia rubescens*) is described as new. The following species are to be added to the fauna of Boulder County:

*Acanthocystis myriospina* Penard?—near Caribou (Penard).

*Actinophrys sol* Ehr.—near Caribou (Penard); University campus, 1908, very abundant (Cockerell; det. Edmondson).

*Amiba limax* Dujardin—near Caribou, 10,000–10,500 ft. (Penard).

*A. verrucosa* Ehr.—near Caribou (Penard).

*A.* sp. (nov.?)—Bald Mtn., about 12,000 ft. (11,470 according to Rydberg's *Flora*)—(Penard).

*A. radiosa* Ehr.—Fawcett's Greenhouse, Boulder, 1908 (Cockerell; det. Edmondson).

[From the discussion recently published by Dr. E. L. Walker, it appears doubtful whether the names *Amiba* and *Chaos* really apply to these animals. The name *Ouramoeba* Leidy, based on a parasitized state of *Amiba* auctt. (Penard, *Rev. Suisse Zoöl.*, XIII, p. 585), appears to be available under the rules.]

*Anisonema acinus* Duj.—Fawcett's Greenhouse, Boulder, 1908 (Cockerell; det. Edmondson).

*Anthophysa vegetans* Müll.—Boulder, 1907 (William Winner; det. Cockerell).

*Arcella vulgaris* var. *angulosa* Leidy—near Caribou (Penard).

*A. discoides* Ehr.—near Caribou (Penard).

*A. microstoma* Penard—near Caribou (Penard), Bald Mtn. (Penard).

*Assulina minor* Penard—near Caribou and Bald Mtn. (Penard).

*Centropyxis aculeata* Stein—near Caribou (Penard).

*Corythion dubium* Taranck.—near Caribou (Penard).

*C. pulchellum* Penard—near Caribou (Penard).

*Cryptodifflugia oviformis* Penard—near Caribou (Penard).

*Cyphoderia margaritacea* Schlumberger—near Caribou (Penard).

*Difflugia arcula* Leidy, *D. lucida* Penard, *D fallax* Penard, *D. bacillifera* Penard and *D. constricta* Ehr., all near Caribou (Penard). *D. constricta* was also found by Penard at an altitude of 12,500 ft., which is said to be the highest altitude known for a Rhizopod.



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*D. rubescens* Penard—Bald Mtn. (Penard). Peculiar for having the plasma of a beautiful brick-red color.

*Euglypha ciliata* Leidy, *E. cristata* Leidy, *E. compressa* Carter and *E. laevis* Perty—all near Caribou (Penard); *E. ciliata* also on Bald Mtn.

*Glenodinium cinctum*—near Caribou (Penard).

*Heleopera rosea* Penard—near Caribou, and Bald Mtn. (Penard).

*Heterophrys* sp.—near Caribou (Penard).

*Lacrymaria truncata* Stokes—Boulder, 1908 (R. Keating). I sent a sketch to Dr. Edmondson, who thinks it is *L. truncata;* it is hardly typical, but he has found that species very variable.

*Lecquereusia jurassica* Schlumberger—near Caribou (Penard).

*Nebela collaris* Leidy, *N. longicollis* Penard, *N. tubulosa* Penard and *N. dentistoma* Penard, all near Caribou (Penard). All except *tubulosa* also on Bald Mtn.
It appears that the prior name for *N. longicollis* is *N. barbata* Leidy.

*Paramoecium trichium* Stokes—Fawcett's Greenhouse, Boulder, 1908 (Cockerell; det. Edmondson).

*Peridinium tabulatum* (Ehr.)—near Caribou (Penard).

*Petalomonas mediocanellata* Stein—Fawcett's Greenhouse, Boulder, 1908 (Cockerell; det. Edmondson).

*Pseudochlamys patella* Clap. & Lach.—near Caribou and Bald Mtn. (Penard).

*Quadrulella* (=*Quadrula* Sch., not Rap.) *symmetrica* (Wallich)—near Caribou (Penard).

*Sphenoderia dentata* Penard—near Caribou (Penard).

*Stylonychia* sp.—Fawcett's Greenhouse, Boulder (Cockerell). "Seems to be identical with the form mentioned on p. 102, *Protozoa of Iowa*, and also referred to in Conn's work" (Edmondson).

*Trinema lineare* Penard, *T. enchelys* var. *galeatum* Penard and *T. complanatum* Penard, all near Caribou (Penard). *T. lineare* also on Bald Mtn.

Dr. Penard has very generously presented to the University a series of 43 slides of Rhizopods from Switzerland, for comparison with our Colorado fauna. He writes that as early as 1899 he had discovered a Rhizopod fauna at the bottom of the Swiss lakes, including a number of species totally absent from shallow waters of the plains. He suggested at the time that these might be the remnants of a fauna existing in glacial times, and raised the question whether they might not be found in small lakes and ponds, very high in the mountains. At the time, nobody seemed to attach any value to this theory; but more recently, through the researches of Zschokke, Monti and others, it appears to be confirmed. At least half a dozen of the deep-water species have occurred at very high altitudes, while they have not been found in shallow waters in the lowlands. Dr. Penard therefore raises the question, whether these deep-water species may not also occur in

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small lakes high in the Rocky Mountains, and sends slides of many of them in order that they may be recognized if found. He further remarks that Leidy found his *Campascus cornutus* at 10,000 ft. in Wyoming, and nowhere else; this species, except for the possession of horns, is nearly the same as *C. triqueter* of the Swiss lakes; the genus itself being extremely curious and characteristic.

The deep-water species (from the bottom of Lake Geneva) sent by Dr. Penard are the following: *Campascus triqueter* Penard, *Cyphoderia ampulla* var. *major* Penard, *C. trochus* Penard, *C. calceolus* Penard, *C. myosurus* Penard, *Difflugia lebes* Penard, *D. histrio* Penard, *D. scalpellum* Penard, *D. elongata* Penard, *D. lemani* Blanc, *D. praestans* Penard, *Euglypha aspera* Penard, *Gromia brunneri* Blanc, *G. saxicola* Penard, *G. squamosa* Penard, *G. linearis* Penard, *Nebela vitraea* Penard, *Pontigulasia bigibbosa* Penard.

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# A FOSSIL GROUND-SLOTH IN COLORADO

By T. D. A. Cockerell

The sloths are characteristic of the neo-tropical region. The modern species, as is well known, are arboreal; three of them occur as far north as Central America. In comparatively recent geological times, ground-sloths of great size lived in South America, and even invaded a large part of our own continent, extending as far as Pennsylvania and Oregon. Many people are familiar with the bones of these extraordinary animals as seen in museums, but until recently, few realized how nearly they came to surviving up to our own times. In 1897 and during subsequent years, a cave in Patagonia was explored, and found to contain not only bones of a ground-sloth (*Grypotherium*), but large pieces of skin with the pale yellowish hair still attached. Some of these were sent to the British Museum in London, where I have seen them. In the same cave were remains of other extinct animals, including a horse, and also those of man. It was believed by the explorers that men inhabited the cave, and kept the *Grypotherium* in a state of domestication; but whether or not this occurred, there is no doubt that they coexisted.

Some time ago the late Mr. E. A. Lidle found on his farm, one mile south of Walsenburg, Colorado, the skull of a large unknown animal. Mrs. Lidle very kindly gave the specimen to the University Museum, and it was brought to Denver and placed in Judge Henderson's hands by Mr. Chas. Hayden. It was very evident that we had a specimen of great value, representing something new to the Colorado list. Upon investigation, it proved to be a ground-sloth, and after comparison with Mr. Barnum Brown's account of *Paramylodon nebrascensis*, from the Pleistocene near Hay Spring, Nebraska (*Bull. Amer. Mus. Nat. Hist.*, XIX, 1903, p. 569), I concluded that we had the second known example of that species. There were, however, certain discrepancies, the most serious being in the number of teeth in the upper jaw. The upper dental series in *Mylodon*, as well as in the living sloths, is five. In our skull, as may be seen from the figures, there are five teeth on each side;



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but in Mr. Brown's *Paramylodon* there were only four, this being one of the principal characters upon which the new genus was based. It seemed possible that the type of *Paramylodon* had lost the anterior tooth, which is a short distance from the others, and not strictly in a line with them. If this could be believed, the other differences might be attributed to individual variation, and the animals referred to the same species.

At this point, photographs of our specimen were sent to Mr. Brown, together with a statement of the difficulties encountered. He has very kindly made comparisons, and has written as follows:

> Our *Paramylodon* skull is perfect. Not any of the palate has been broken away, and there never were but four teeth on a side. In Edentates the contour of the tooth is accurately defined by the alveolus, so we are pretty safe in comparing the two skulls that way. Thus in the two skulls the pattern of teeth is similar if not identical in the last four. The dental series in your skull, however, seems much farther forward, and presumably the teeth are smaller. The distance from the last molar to the post-palatine notch is greater in your skull; condyles are wider apart and placed parallel with axis of skull as in South American *Mylodons*. Our skull is narrower across orbits and occipital region is narrower; musculature not so well defined. Shortly after I published, Harvard University secured a nearly complete skeleton of *Mylodon* from the same Hay Spring region, and I believe it is the same species that you have. (April 10, 1909.)

I also sent photographs of the Colorado skull to Dr. Chas. W. Andrews, of the British Museum, who replied that so far as he could judge from them, he could not see why the animal should be separated from *Mylodon*. The total length of our skull is 540 mm., and the width of the muzzle at its widest part is 150, or a trifle less. The animal was doubtless as large as a rhinoceros. The first upper tooth is very much smaller than the second, and is placed 6½ mm. from it. The socket is oval in outline, with the greater diameter 22 mm.; only a portion of the root of the tooth remains. The other teeth, judging from the sockets, were in exact agreement with *Paramylodon*.

The measurements of the alveoli of four last teeth (corresponding with those present in *Paramylodon*) are as follows: (1) long. 37, lat. 19 mm.; (2) long. 38, lat. 30 mm.; (3) long. 34, lat. 22 mm.; (4) long.

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32 mm. The distance from the last alveolus to the posterior nares is 58 mm. Thus it seems that the teeth in our animal were both actually, and in a slight degree relatively, larger than in *Paramylodon*. The distance from the last alveolus to the posterior nares in *Paramylodon*, as measured from Mr. Brown's figure, would be about 48 mm.

The elongate skull, and inflated muzzle, given by Mr. Brown as generic characters of *Paramylodon*, are equally noticeable in the Colorado animal. The trilobed last molar of lower jaw, also said to be a generic character of *Paramylodon*, is in some degree indicated in *Mylodon harlani*, according to Leidy's figure in his Smithsonian Memoir of 1855. The slope of the occipital region, as seen in lateral profile, is equally characteristic of our skull and *Paramylodon;* so also is the broadening of the muzzle anteriorly. These characters are equally well seen in the existing sloth *Cholœpus hoffmanni*, found in Costa Rica, but are much less evident in the other living Central American genus, *Bradypus*. Gray's figure (*Proc. Zoöl. Soc.*, 1871) of the skull of the Brazilian *Choloepus didactylus* does not exhibit the occipital character at all, and is surprisingly unlike *C. hoffmanni;* but Dr. J. A. Allen assures me that the difference is due to immaturity, as De Blainville's figure of the skull of *C. didactylus* shows no material difference from skulls of *C. hoffmanni*. In the Pleistocene *Megalonyx* the slope of the occiput is less extreme, and the whole skull is much less elongated than in *Paramylodon*.

It is to be noted that a *Mylodon* fibula was found some years ago at Seneca, Kansas, and described and figured by Dr. Williston in the *Kansas University Quarterly*, January, 1895. Dr. Williston referred it with doubt to *Mylodon harlani*, but the general measurements accord better with those given by Brown for the fibula of *Paramylodon*, showing merely an excess of ten millimeters. However, Mr. Brown writes me that the Kansas fibula must certainly be referred to *Mylodon*, having the tibial and astragalar facets separate, whereas they are continuous in *Paramylodon*. The fibula of *Paramylodon* is also more slender than that of *Mylodon*.

Provisionally, it is perhaps justifiable to consider our skull referable

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to a new species of *Mylodon*, but before it can be satisfactorily described as such it will be necessary to reconsider the whole subject of the *Mylodontinae*, as represented in the North American Pleistocene.

The Walsenburg locality is on the dividing-line between the Pierre and Trinidad formations, but it is evident that there must be a residual patch of Pleistocene deposit. Whether other bones can be found there, and especially whether the Colorado animal can be proved contemporaneous with man, must for the present remain unknown. The discovery is, to say the least, suggestive of most interesting possibilities.

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A Fossil Ground-Sloth in Colorado

Plate I

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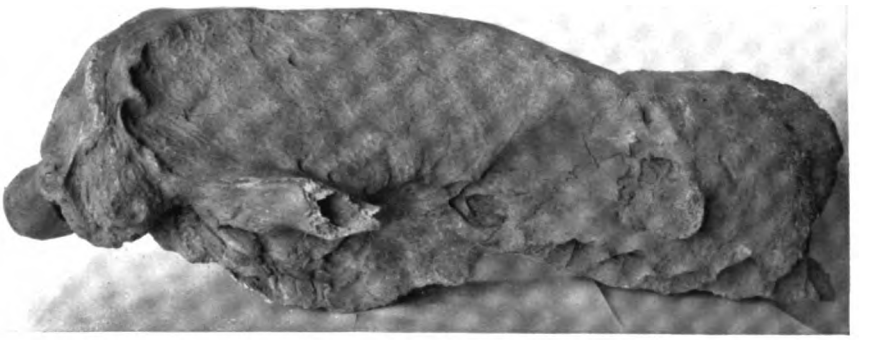

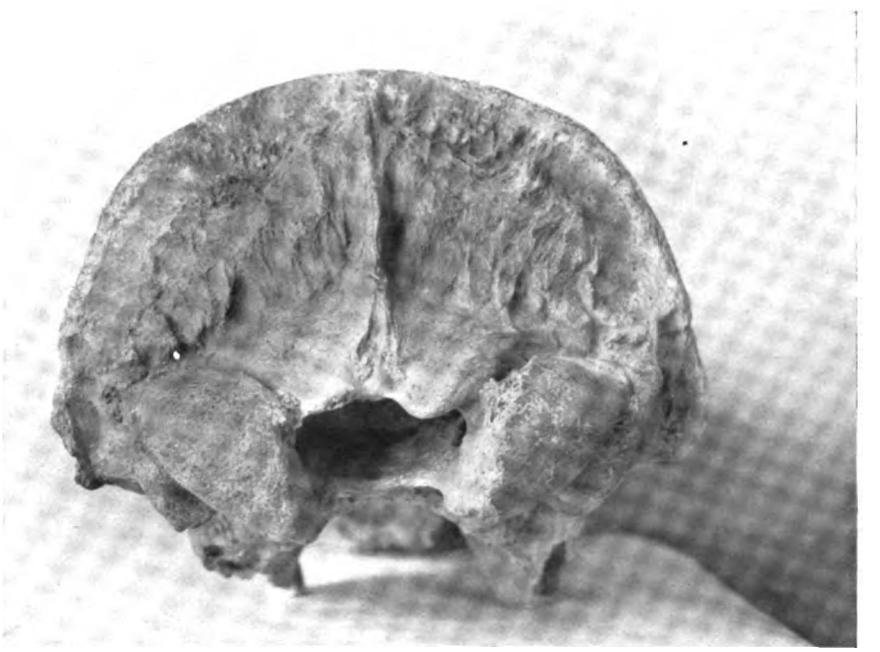

A Fossil Ground-Sloth in Colorado

Plate II

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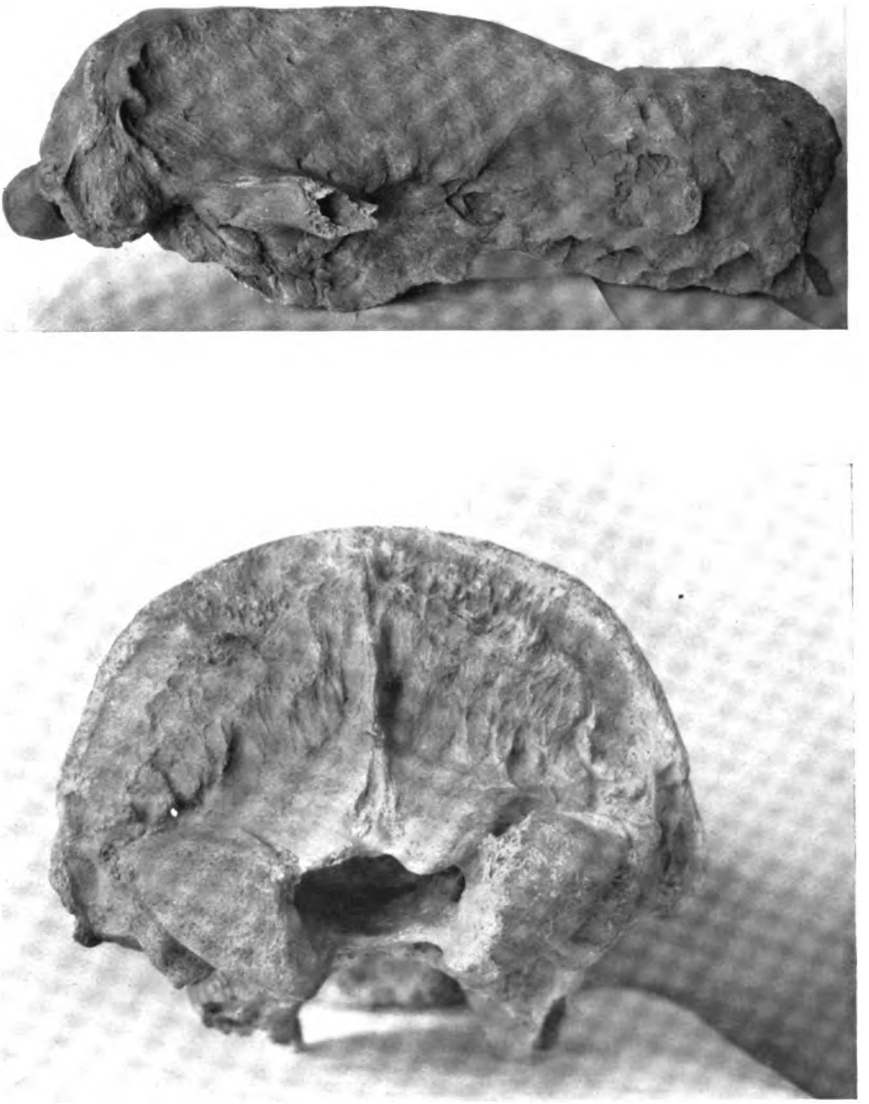

A Fossil Ground-Sloth in Colorado

Plate II

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# NOTE ON THE HEATING EFFECTS PRODUCED IN METALS BY BOMBARDMENT WITH KATHODE RAYS

By Oliver C. Lester

During the year 1905 Professor H. A. Bumstead of Yale University investigated the heating effects produced in lead and zinc when they were exposed to Roentgen rays and found that, when the two metals received the same amount of energy in the form of radiation from an X-ray tube, approximately twice as much heat was developed in the lead as in the zinc.[1] He explained this result as probably due to the fact that the X-rays exerted a trigger-like action on the more unstable molecules of lead, causing some of them to disintegrate, thereby liberating atomic energy. This apparent difference in the effect on lead and zinc was afterward found by Professor Bumstead to be due to an error caused by the imperfect heat insulation of the two metals.[2] Both his own later work and that of other investigators show that while there may be liberation of atomic energy due to the action of the Roentgen rays, it is not a large enough fraction of the total energy produced to be detected by the means employed.

In the year 1906 the writer, then at Yale University, undertook, at Professor Bumstead's suggestion, a similar investigation, using kathode rays as the energizing agent. It is well known that the negatively charged kathode particles, under proper conditions, possess a great amount of energy, as is shown by their penetrating, heating and other familiar effects. There was thus the possibility that two metals, differing considerably in atomic weight, might develop different amounts of heat when bombarded with kathode rays though each should receive the same amount of energy. For, if enough energy could be communicated to the atoms to render them unstable and cause them to disintegrate, the metal composed of the most unstable atoms should ultimately

[1] "Heating Effects Produced by Roentgen Rays in Different Metals and Their Relation to the Question of Change in the Atom," *Phil. Mag.*, Vol. II, p. 292, 1906.

[2] *American Journal of Science*, p. 299, April, 1908.



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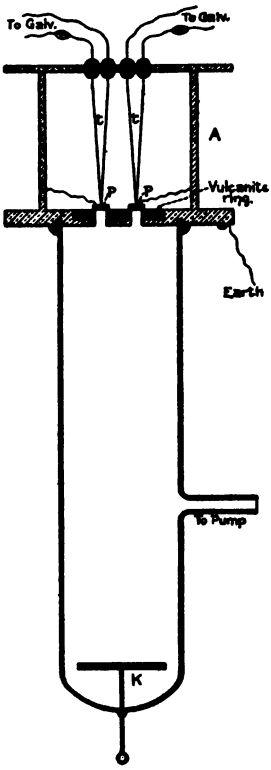
reach the higher temperature owing to the liberation of atomic energy. Any considerable difference in heat development ought to be capable of detection by suitably placed thermoelectric couples and a sensitive galvanometer. It was on this basis of theory that the experiments were undertaken.

The experimental difficulties were unusually great and necessitated many preliminary experiments to overcome them. The arrangement of apparatus finally adopted is shown in the figure which is an axial section. The vacuum tube was about 20 cm. in length by 3 cm. internal diameter. The kathode was a flat piece of aluminum of about 2 cm. diameter insuring a bundle of rays considerably larger than the target offered by the plates. The anode *A* was a brass cap forming a Faraday cylinder. On opposite sides of this brass cap were cut two windows (not shown in the figure) covered by glass and wire gauze, which permitted an inspection of the positions of the plates and thermoelectric couples at all times. The Zn plate was 1.1 cm. long, 3 cm. wide and 0.075 cm. thick; the Pb plate 1.1 cm. long, 3 cm. wide and 0.025 cm. thick. The difference in thickness was to allow for the difference in conductivity. Both the conductivity and the specific heat of zinc are approximately three times that of lead. Both plates rested upon a vulcanite ring sunk flush with the surface of the brass plate, as indicated in the figure. The openings beneath the plates were of exactly the same size, 1 cm. by 0.2 cm., and symmetrically placed in the bundle of kathode rays. To prevent static charges affecting the galvanometer, the plates, the brass cap, and the galvanometer case were earthed. The wires by which the plates were earthed were exceedingly fine and of the same length, so that what little loss of heat occurred

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in this way should have been about the same for each plate. There was practically no loss of heat by conduction through the vulcanite. The loss by radiation was equalized by coating both plates with thin aluminum leaf. The heat losses from all causes were slight, for the temperature in the tube was never raised more than a few degrees. The plates were held in position by small drops of water-glass placed at each end and by the pressure of the thermoelectric couples placed at the centers of their back faces. Any asymmetry in the bundle of kathode rays could be eliminated by rotating the vulcanite ring to which the plates were attached.

The thermoelectric couples were made by joining No. 24 Ni and Cu wires at an angle of about 30° with silver solder. The junctions were then filed away until they presented points about 0.25 mm. square in area. The wires were insulated by small glass tubes and sealing-wax where they passed through the the brass cap. The second Ni and Cu junctions, outside the tube, were protected from air currents and sudden changes in the room temperature by lumps of soft wax molded around them, a device which served its purpose admirably by eliminating entirely the previous erratic behavior of the galvanometer. The resistances and the thermoelectric properties of the couples were tested in various ways and found to be practically identical.

With the above arrangement, which was exceedingly sensitive to changes in temperature at the junctions within the tube, many experiments were made, the results of which show no appreciable difference in the heating effects produced in lead and zinc. With other arrangements the results were erratic, sometimes showing a heating effect greater in the lead and again greater in the zinc. In almost all such cases the real heating effects were found to be masked by static charges which accumulated because of imperfect grounding. My assistant, Mr. F. A. Giacomini, repeated some of the experiments in 1907 with a slightly modified form of apparatus and his results confirm those obtained before. All the results obtained have been reduced to the form of curves but as they present nothing particularly new it does not seem necessary to publish them. The main object of this note is to make known the general results obtained by the method of attacking the problem described above.

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# ALPHABETICAL INDEX TO VOL. VI


PAGE

Allison, Edith M. . . . . 51
Annotated List of Birds of Boulder County, Colorado . . . . . 219
Ayer, Charles C. . . . . 287

Bibliography and History of Colorado Botany . . . . . 51
Birds of Boulder County, Colorado . . . . . 219
Botanical Opportunity in Colorado . . . . . 5
Boulder, Colo., Mesas near . . . . . 11

Chadwick, George M. . . . . 299
Character of the Flavian Literature, The . . . . . 18
Climatology of the Mesas near Boulder, Colorado . . . . . 19
Cockerell, T. D. A. . . . . 305, 309
Colorado
  Botany . . . . . 5, 19, 31, 36, 51, 133, 249
  Climatology . . . . . 19, 138
  Entomology . . . . . 243
  Geology . . . . . 11, 97
  Mineralogy . . . . . 93
  Ornithology . . . . . 219
  Palaeontology . . . . . 309
  Tungsten Ores . . . . . 93
  Zoölogy . . . . . 219, 243, 305
Composition of Some Colorado Tungsten Ores . . . . . 93
Crawford, R. D. . . . . 97

Distribution of Conifers on the Mesas (near Boulder) . . . . . 31
Dodds, Gideon S. . . . . 11, 31
Drama, Foreign . . . . . 287

Edson, Carroll E. . . . . 173
Electrochemistry of the Solution of Gold in Potassium Cyanide . . . . . 215
Ekeley, John B. . . . . 93, 215

Flavian Literature . . . . . 81
Foreign Drama on the English and American Stage . . . . . 287
Forest Formations and Forest Trees . . . . . 249
Fossil Ground-Sloth in Colorado . . . . . 309
French Drama . . . . . 287

Geology and Petrography of the Sugarloaf District, Boulder County, Colorado . 97
Geology and Physiography of the Mesas near Boulder, Colorado . . . . . 11
Ground-Sloth in Colorado, A Fossil . . . . . 309




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Heating Effect by Bombardment with Kathode Rays . . . . . 313
Hellems, Fred B. R. . . . . 81
Henderson, Junius . . . . . 219
History and Bibliography of Colorado Botany . . . . . 51

Lake and Streamside Vegetation . . . . . 131
Lester, Oliver C. . . . . 313

Mesas near Boulder; Geology, Climatology, and Botany . . . . . 11

Note on the Heating Effects Produced by Bombardment with Kathode Rays . 313
Notes on Protozoa . . . . . 305

Opportunity, Botanical, in Colorado . . . . . 5
Organ Transcriptions . . . . . 299

Protozoa, Notes on . . . . . 305

Ramaley, Francis . . . . . 5, 19, 133, 249
Redrock Lake near Ward, Colorado . . . . . 133
Robbins, W. W. . . . . 31, 36, 133

Silva of Colorado, The . . . . . 249
Studies in Lake and Streamside Vegetation . . . . . 133
Studies in Mesa and Foothill Vegetation . . . . . 11
Sugarloaf District, Geology and Petrography of . . . . . 97

Tatum, Arthur L. . . . . 215
Théodore Tronchin: A Fashionable French Physician of the Eighteenth Century . 173
Tronchin, Théodore . . . . . 173
Tungsten Ores . . . . . 93

Vegetation, Lake and Streamside . . . . . 133

Ward, Colo., Redrock Lake near . . . . . 133

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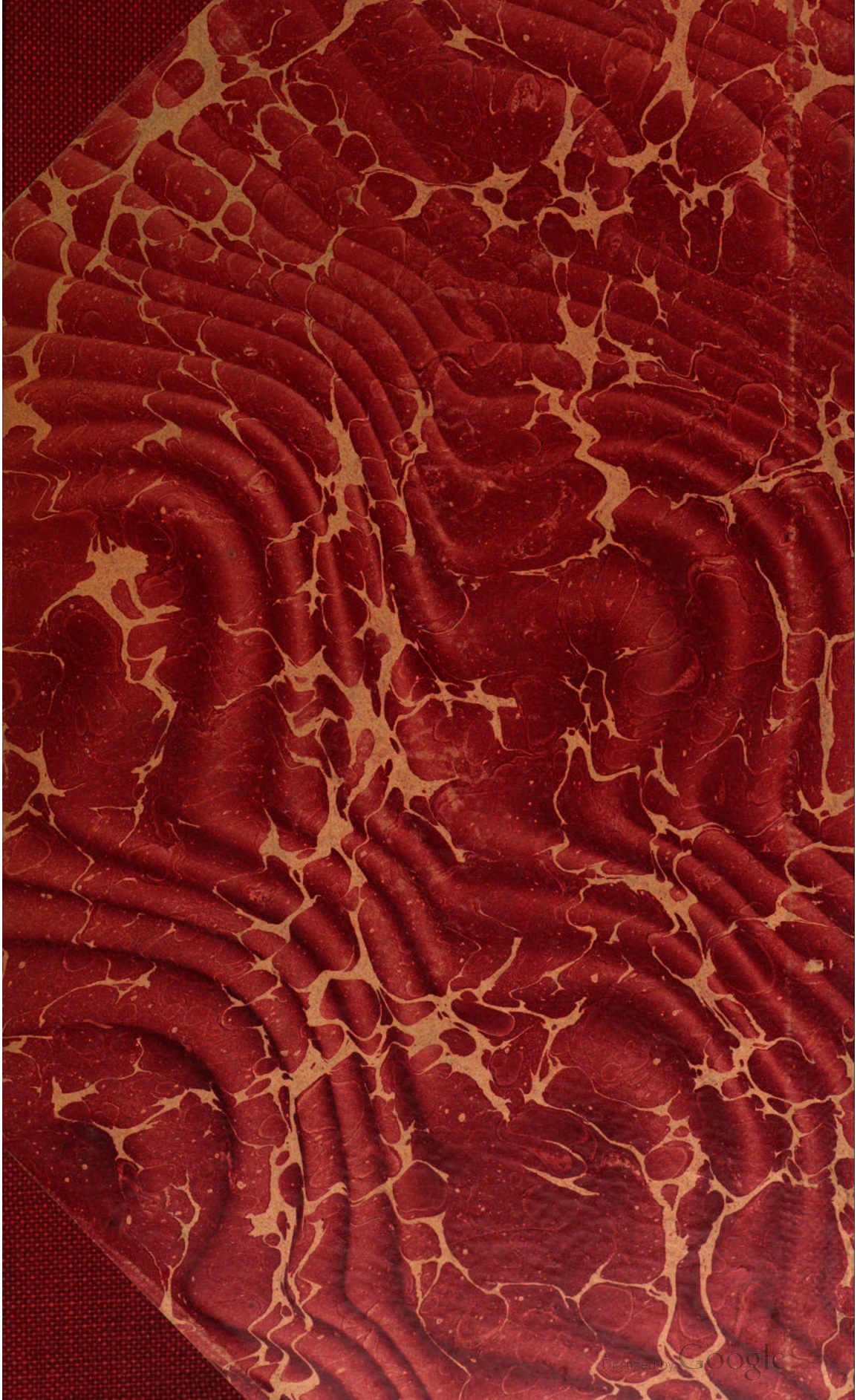
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